Utah Energy Facility Siting Study

Survey of
Literature Relating
to Energy Development
in Utah's
Colorado Plateau

Utah Consortium for Energy Research and Education
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**SURVEY OF LITERATURE RELATING TO ENERGY
DEVELOPMENT IN UTAH'S COLORADO PLATEAU**

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SECTION I

INTRODUCTION AND SCOPE OF STUDY

This study, which was commissioned by the Utah Consortium For Energy Research and Education, examines various energy resources in Utah including oil impregnated rocks (oil shale and oil sand deposits), geothermal, coal, uranium, oil and natural gas in terms of the following dimensions:

- Resource potential and location
- Resource technology, development and production status
- Resource development requirements
- Potential environmental and socio-economic impacts
- Transportation tradeoffs

In addition, this study also examines the advantages of minemouth power plants in comparison to combined cycle or hybrid power plants.

Annotative bibliographies of the energy resources are presented in Appendices C through J. Specific topics summarized in these annotative bibliographies include: economics, environmental impacts, water requirements, production technology, and siting requirements. These bibliographies do not represent an exhaustive literature search, but do show conclusions of current, 1975 to 1978, research work.

Table I-1 shows an inventory as of January 1, 1980 of Utah's Energy Resources. Table I-2 summarizes the Utah Geological and Mineral Survey estimate of recoverable resources.

TABLE I-1
INVENTORY OF UTAH'S ENERGY RESOURCES

January 1, 1980

Column	1	2	3	4	5
Resource	Estimate of Reserve or Resource (Gross) Year First Produced	Estimate of Total Production to End of 1979	Total Remaining of Reserve (Percent)	Estimate % Recoverable (of Col. 3)	Possible Additional Resource (Inferred/Speculative Category)
Coal	24.00 billion short tons 1850 (1) 1870 (2) Resource-Gross	0.40 billion short tons (398 million short tons)	23.60 billion short tons (98.4%)	(4)	15.00 billion short tons (3)
Oil & Natural Gas Liquids	915,000,000 barrels 1907 Reserve	690,000,000 barrels	225,000,000 barrels (25%)	Near 100%	250-300 million barrels
Natural Gas	3.10 trillion cu. ft. 1895 (1) 1928 (2) Reserve	1.80 trillion cu. ft.	1.30 trillion cu. ft. (7) (42%)	85 - 90%	0.850 to 0.900 trillion cu. ft. (850 to 900 billion cu. ft.)
Oil- impregnated sandstone	28.00 billion barrels of oil in place No production Resource-Gross	None	28.00 billion barrels of oil in place (100%)	15 - 20%	1.5 - 2.0 billion barrels
Uranium	35.0 million short tons (5) Reserve	18.7 million short tons	16.3 million short tons (5) (47%)	(4)	No estimate
Oil Shale	120 billion barrels (6) 1977 Resource-Gross	8,400 bbls.	120 billion barrels (6) (100%)	35 - 40%	
<div> <div> (1) Approximate first production. (2) First records kept. (3) Under less than 3,000 ft. of cover. </div> <div> (4) No estimate of % recoverable (5) 0.26% grade (approximate) (6) 25+ gallons per ton grade, 10 or more feet thick (7) Includes reserves of sour gas and gas in tight sands and gas being used in pressure maintenance and secondary recovery operations, most of which will become producible in future. </div> </div>					

Source: H. R. Ritzma
Utah Geological and Mineral Survey

Table I-2
 UTAH'S RECOVERABLE ENERGY RESOURCES
 (January 1, 1980)

<u>Resource</u>	<u>Remaining Reserve</u>	<u>Percent Remaining</u>
Coal	23.60 billion short tons	98.4%
Oil and Natural Gas Liquids	225 million barrels	25.0
Natural Gas	1.3 trillion cubic feet	42.0
Oil-impregnated Sandstone	26.00 billion barrels of oil in place	100.0
Uranium	16.3 million short tons	47.0
Oil Shale	120 billion barrels	100.0

Source: Utah Geological and Mineral Survey

In summary, the comparative risks and benefits from the generation and distribution of electricity are presented below:

<u>Type of Plant</u>	<u>Comparative Risks</u>	<u>Comparative Benefits</u>
Hydroelectric	Alteration of stream flow; destruction of habitats and scenery, such as by reservoirs and long transmission lines	Energy; employment; flood control; recreation
Gas-fired	Destruction of scenery, such as by pipelines and plant stacks; air pollution with many substances; alteration of local ecology by thermal waste	Energy; employment; by-products
Oil-fired	Destruction of scenery, such as by pipelines, storage tanks, plant stacks, and ash disposal areas; water pollution; air pollution with many substances; alteration of local ecology by thermal waste	Energy; employment; by-products
Coal-fired	Destruction of scenery, such as by strip mining, transport and storage facilities, plants, stacks, and ash-disposal areas; stream pollution (from mining refuse); air pollution with many substances; alteration of local ecology by thermal waste	Energy; employment; by-products
Nuclear	Destruction of scenery, such as by mining and processing facilities plants, and stacks; minimal routine air and water pollution with radioactive ash; possible leakage during the long-term confinement of high-level radioactive wastes from fuel reprocessing facilities; possible accidental release of significant quantities of radioactivity due to a reactor malfunction; alteration of local ecology by thermal waste	Energy; employment; by-products (i.e., isotopes useful in medicine, industry, research, etc.)

SECTION II

OIL SHALE AND OIL DEVELOPMENTS

This section examines the oil shale and tar sand developments in Utah. Oil shale is neither oil nor shale, but rather, a fine-grained sedimentary rock containing organic matter which yields substantial quantities of oil upon pyrolysis which is a chemical change caused by heat.¹ Tar sands, oil sands, bituminous bearing rock, oil impregnated rocks and bituminous sands are all terms used interchangeably in describing hydrocarbon bearing deposits.² These kinds of deposits are differentiated from common oil and gas reserves by the high viscosity of the hydrocarbon which is currently not recoverable in its natural state by existing oil production technology.³

Resource Potential and Location

As of January 1, 1980, the Utah Geological and Mineral Survey of Utah's Department of Natural Resources estimated that 120 billion barrels of oil are in place from oil shale deposits (25 plus gallons per ton grade, 10 or more feet thick) and that 26 billion barrels of oil are in place from oil sand deposits. (See Table I-1.) The department further estimates that 35 to 40 percent of the oil sands or 3.9 to 5.2 billion barrels of oil are recoverable with known technology. Figures II-1, II-2 and II-3 present maps of Utah's oil shale deposits and oil sands, respectively.

Specific geographical descriptions of the oil shale and tar sand deposits are presented in Table II-1 and Figure II-4.

Table II-1
OIL SHALE RESOURCES
(In Billion Barrels)

<u>15 Gallon/Ton</u>	<u>In Place</u>	<u>Recoverable</u>
Colorado	1,200	400
Wyoming	321	105
Utah	321	105
 <u>25 Gallon/Ton</u>		
Colorado	607	202
Wyoming	60	20
Utah	64	21
 <u>30 Gallon/Ton</u>		
Colorado	355	118
Wyoming	13	4
Utah	50	17

Source: U.S. Department of Interior. Project Independence. Task Forces Report, Future Role of Oil Shale: Prospects and Constraints, 1974, p. 105

Figure II-1

Location of Oil Shale Resource
In the Green River Formation

Source: Project Independence Task Force Report, Future Role of Oil Shale: Prospects and Constraints, 1974, p. 2.

Figure II-2

OIL SHALE AREAS UINTAH BASIN, NORTHEAST UTAH

-4-

File no. 1363-A

Figure II-3

Utah Geological and Mineral Survey
Department of Natural Resources

(DOTTED AREA SHOWS EXTENSION
INTO SUBSURFACE)

Another estimate of Utah's recoverable oil shale also confirms the one made by the Utah's Department of Natural Resources. This estimate suggests that Utah can recover approximately 39 billion barrels of shale oil in the 25 to 30 gallon per ton deposit range. In the 15 gallon per ton range, Utah is expected to have 105 billion barrels of recoverable shale oil. Figure II-4 shows the location of seven different oil shale deposit classifications in the Uintah Basin area. Cameron and Jones, a Colorado Engineering Company, estimates the land requirements needed to support a 25,000 barrel per day commercial plant--20 year operation. (See Table II-2.) An extensive description of oil impregnated rock deposits or tar sand deposits is shown in Table II-3.

The three largest tar sand deposits are found in the following counties: Garfield and Wayne Counties--Tar Sand Triangle deposit, Uintah and Grand Counties--P.R. Spring deposits, and Carbon County--Sunny-side deposit.

Resource Production, Technology and Development Status

Oil Shale

Currently there are three major oil shale projects which include the White River Shale Project, the Tosco Sand Wash Project and the Geokinetics development. Table II-4 presents a summary of oil shale production and properties in Utah. The Uintah Basin Association of Governments and Utah's Energy Office recently published a document that assesses the development of oil shale and oil sands in Utah. The report summarizes oil shale developments as follows:

White River Shale Project

The project is clouded with pending court resolution of title conflicts which resulted in

suspending federal lease terms in May 1977. This project is expected would produce 100,000 barrels of shale oil per day. Until the legal problems are resolved, there is not further development planned.

Tosco Sand Wash Project

The project is located on five tracts of non-contiguous state oil shale leases in the Central portion of the Uintah Basin. Under a unitization agreement with the state, Tosco has agreed to invest a minimum of \$8 million by 1984 for pre-development activities. Currently underway are city exploration activities, environmental monitoring and shaft sinking. The project is expected to produce 47,000 barrels of shale oil per day once commercial operations commence.

Geokinetics Inc. Project

This project is currently the only oil shale project in the state to have produced any significant amount of shale oil. While classifying their work as Research and Development, Geokinetics has produced approximately 6,000 barrels of synthetic crude. By 1982 the Company expects to produce 2,000 barrels per day. The company expects to expand to 20,000 barrels per day if federal lands become available for leasing and some form of financial assistance can be procured.⁵

See Figure II-5 for a detailed location analysis of these developments.

Total oil shale production in the State of Utah could be in the range of 150,000 barrels per day by 1990 given no serious barriers develop that would prevent these developments from reaching their production targets.⁶

A summary of the current technology for recovering shale oil is presented in Table II-5. Basically there are three types of oil shale retorting processes which include surface retorting, in situ retorting and multimineral recovery.

Figure II-4

Classification of Uintah
Oil Shale Deposits

LEGEND

- SURFACE OUTCROP OIL SHALE MEASURE UINTA BASIN
- - - - ESTIMATED UNDERGROUND BORDER OIL SHALE MEASURE UINTA BASIN
- CLASS A OPEN PIT MINE MINIMUM 30 FEET CONTINUOUS THICKNESS
15 GPT OIL SHALE, 1.5 TO 1 MAXIMUM OVERBURDEN TO OIL
SHALE RATIO, 0-250 FEET OVERBURDEN
- CLASS B 2 LEVEL UNDERGROUND MINE, 50 FEET MINIMUM CONTINUOUS
THICKNESS 26 GPT OIL SHALE, 0-1500 FEET OVERBURDEN
- CLASS C SINGLE HEADING UNDERGROUND MINE, 25-50 FEET CONTINUOUS
THICKNESS 28 GPT OIL SHALE, 0-1500 FEET OVERBURDEN
- CLASS D IN SITU ONLY POSSIBILITY, MINIMUM 30 FEET CONTINUOUS
THICKNESS 15 GPT OIL SHALE, 1500 TO 6500 FEET OVERBURDEN
- CLASS E NO COMMERCIAL INTEREST, LESS THAN 30 FEET CONTINUOUS
THICKNESS 15 GPT OIL SHALE
- CLASS F INSUFFICIENT INFORMATION FOR CLASSIFICATION BUT PROBABLY
IS CLASS D OR E
- CLASS G INSUFFICIENT INFORMATION FOR CLASSIFICATION

Figure II-4a

Table II-2

AREA REQUIREMENTS TO SUPPORT
A COMMERCIAL PLANT ¹

<u>Class</u>	<u>Shale Grade (Gallons Per Ton)</u>	<u>Shale Thickness (Feet)</u>	<u>Mining Plus Retorting Recovery Efficiency</u>	<u>Area Required Acres</u>
A	15	200	90%	880
B	25	65	67%	2340
C	25	25	67%	6100
D	15	50	50%	6400

¹25,000 Barrel Per Day Commercial Plant For 20 Years.

Source: Cameron and Jones, INC., p.33.

Table II-3

Oil-Impregnated Rock Deposits of Utah
(1978)

<u>County</u>	<u>Deposit</u>	<u>Size of Deposit</u>	<u>Gross Oil In Place</u> (In Million Barrels) ¹	<u>Areal Extent</u> (In Square Miles)	<u>Number of Principal Pay Zones</u>	<u>Gross Thickness of Range</u> (In Feet)	<u>Overburden Thickness Range</u> (In Feet)
Box Elder	Rozel	Minor	-	-	-	-	-
Carbon	Sunnyside	Giant	3,500-4,000	35-90	3-12	15-550	0-500+
Carbon & Duchesne	Cottonwood-Jacks Canyon	Large	20-25	-	-	-	-
	Minnie Maud Creek	Large	10-15	0.5-3.5	1-4	5-15	0-500+
Duchesne	Argyle	Large	50-75	7-15	3-5	15-60	0-500+
	Lake Fork	Medium-Small	6.5-10	0.3-0.5	1-3	5-70	0-450
	Nine Mile	Medium-Small	5-10	-	-	-	-
	Spring Branch	Medium-Small	1.5-2	0.1-0.2	1	5-250	0-350
	Tabiona	Medium-Small	4.6	.15	1-3	5-150	0-400
Duchesne & Uintah	Pariette	Large	12-15	1.2-1.4	1 or 2	5-32	0-300
Duchesne, II Utah and Wasatch	Willow Creek	Large	10-15	-	-	-	-
Emery	Black Dragon	Very Large	100-125	-	-	-	-
	Chute Canyon	Large	50-60	-	-	-	-
	Cottonwood Draw	Large	75-80	10.5-12.0	1-3	5-65	0-500+
	Family Butte	Very Large	100-125	-	-	-	-
	Flat Top	Minor	.25-.50	-	-	-	-
	Justensen Flat	Minor	-	-	-	-	-
	Red Canyon	Large	60-80	-	-	-	-
	San Rafael Swell	Minor	-	-	-	-	-
	Sweetwater Dome	Minor	.10-.12	-	-	-	-
	Temple Mountain	Minor	-	-	-	-	-
	Wickiup	Large	60-75	-	-	-	-

Table II-3 Con't

<u>County</u>	<u>Deposit</u>	<u>Size of Deposit</u>	<u>Gross Oil In Place (In Million Barrels)</u>	<u>Areal Extent (In Square Miles)</u>	<u>Number of Principal Pay Zones</u>	<u>Gross Thickness of Range (In Feet)</u>	<u>Overburden Thickness Range (In Feet)</u>
Garfield	Circle Cliffs, East Flank	Giant	860	21.1	1-3	5-260	0-500+
	Circle Cliffs, West Flank	Very Large	447	6.6	1or2	5-310	0-500+
	Muley Twist	Minor	-	-	-	-	-
	Poinson Spring Canyon	Medium-Small	1.0-1.2	0.6-0.8	1or3	5-24	0-500+
	Tar Sand Triange	Medium-Small	3	200-230	1or2	5-300	0-500+
	White Canyon Flat	Medium-Small	2.8	0.3-0.4	1	5-21	0-220
Garfield & Wayne	Tar Sand Triange	Giant	12,500-16,000	200-230	1or2	5-300	0-500+
Grand	Salt Wash	Minor	.20-.25	-	-	-	-
	Ten Mile Wash	Medium-Small	6	5.0-6.5	1-4	5-30	0-500+
Kane	Bennetts Seep	Minor	-	-	-	-	-
San Juan	White Canyon	Large	12-15	-	-	-	-
	Mexican Hat	Medium-Small	.4-.5	-	-	-	-
Uintah	Asphalt Ridge	Giant	1,048	20-25	2-5	10-135	0-500+
	Asphalt Ridge, Northwest	Very Large (much in Subsurface)	100-125	5-10	1-3	20-300	0-275
	Chapita Wells	Medium-Small	7.5-8	.35-1.0	1-3	5-30	0-300
	Cow Wash	Medium-Small	1.0-1.2	0.08-0.10	1	5-25	0-200
	Hill Creek	Giant	1.160	115-125	1-3	5-35	0-500+
	Littlewater Hills	Large	10-12	0.5-1.75	1or2	5-90	0-500+
	Raven Ridge	Large	75-100	20-25	1-4	5-48	0-500+
	Rim Rock	Large	25-30	2.0-3.0	1-3	5-95	0-500+
	Split Mountain	Minor	-	-	-	-	-
	Spring Hollow	Minor	-	-	-	-	-
	Upper Kane Hollow	Minor	-	-	-	-	-
	Whiterocks	Very Large	10-15	0.6-0.75	1	1,000+	0-500
Uintah & Grand	P. R. Spring	Giant	4,000-4,500	240-270	2-6	10-80	0-500+

Table II-3 Con't

<u>County</u>	<u>Deposit</u>	<u>Size of Deposit</u>	<u>Gross Oil In Place (In Million Barrels¹)</u>	<u>Areal Extent (In Square Miles)</u>	<u>Number of Principal Pay Zones</u>	<u>Gross Thickness of Range (In Feet)</u>	<u>Overburden Thickness Range (In Feet)</u>
Utah	Thistle	Medium-Small	2.2-2.5	-	-	-	-
Wasatch	Daniels Canyon	Minor	-	-	-	-	-
Washington	Gould Ranch	Minor	-	-	-	-	-
	Hurricane Cliffs	Minor	-	-	-	-	-
	North Creek	Minor	-	-	-	-	-
	Timpoweap Canyon	Medium-Small	0.5-1.0	-	-	-	-
Wayne	Teasdale	Minor	-	-	-	-	-
	Thousand Lake Mountain	Minor	-	-	-	-	-

¹Barrel=42 Gallons

Areal Extent: is generally given as a range, the minimum figure being the measured areal extent, the maximum being the indicated extent.

Number of Pay Zones: is the number of oil-impregnated Rock units five or more feet thick likely to be encountered at any one location within the measured or indicated areal extent of the deposit.

Overburden Thickness: is from outcrop to 1,320 feet (0.25 mile) from outcrop. Variations shown emphasize importance of topography in evaluation of these deposits.

Source: Utah Geological and Mineralogical Survey, Map 47, Sheet 2.

Table II-4

**Oil Shale Production and Properties in Utah
(1979)**

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production</u>
Duchesene	Melvin J. Abbott Duchesne, UT 84021	Sherman No. 3, sec. 6, T. 11 S., R. 12 E.	NO
	Terry P. Abbott Duchesne, UT 84021	Sherman Nos. 1, 2, sec. 5, T. 11 S., R. 12 E.	NO
	George H. Lowe and Ralph J. Lowe 1110 First Security Bldg. Ogden, UT 84401	Little Johnny, American, sec. 1, T. 11 S., R. 11 E.	NO
Summit	Utelite Corp. R. F. D. Coalville, UT 84017	Utelite plant, sec. 8, T. 1 S., R. 5 E., Wanship area, North Summit school district	NW
Uintah	Howard A. Acheson 930 Park Ave. New York, NY 10028	tracts 7, 8, sec. 28, T. 9 S., R. 25 E.	NO
	Jack L. Ashton Vernal, UT 84078	Little Seam	NO
	Atlantic Richfield Co. P.O. Box 2679 Los Angeles, CA 90051	Leroy, Big Jim, Wilma, Little John, Little Jim, Pine Ridge, secs. 8, 9, 13, 17, T. 13 S., R. 24 E.	NO
	Cedar Butte Oil Co. 615 So. Flower St. Los Angeles, CA 90017	Cedar Butte, sec. 19, T. 2 N., R. 1 E., sec. 24, T. 2 N., R. 1 W.	NO

Table II-4 Con't

R. F. Collett et al. 2925 Golden Rain Rd. No. 9 Walnut Creek, CA 94595	Collett, sec. 31, T. 12 S., R. 20 E.	NO
Colorado-Utah Oil Shale Co. 550 Thatcher Bldg. Pueblo, CO 81003	Pueblo 1-6, secs. 28, 29, 30, T. 11 S., R. 25 E.	NO
Exxon Corp. P.O. Box 2180 Houston, TX 77001	Royal 1-8, secs. 1, 2, 11, 12, 13, 14, T. 13 S., R. 23 E.	NO
Geokinetics, Inc. 288 Buchanan field Rd. Concord, CA 94520	Utah Experimental site No. 1, In-situ retorting shale facility, secs. 2, 32, T. 13, 14 S., R. 22 E.	NW
Gregory & Henderson 43 East 200 North Vernal, UT 84078	Pine View, secs. 8, 9, T. 13 S., R. 25 E.	NO
James Ivers, Jr. 810 Tribune Bldg. Salt Lake City, UT 84111	Alamo, secs. 8, 16, 17, 20, 21, T. 10 S., R. 25 E.	NO
T. M. Keele P.O. Box 102 Vernal, UT 84078	Keele, sec. 26, T. 4 S., R. 22 E	NO
Frederick H. Larson c/o Gulf Oil Co. P.O. Box 2100 Houston, TX 77001	Hell Hole, Alamo, T. 10 S., R. 25 E.	NO
Phillips Petroleum Co. 1423 Security Life Bldg. Denver, CO 80202	Phillips Petroleum properties, secs. 6, 7, 8, 17, 18, 20, 21, 27, 28, T. 11 S., R. 25 E.	NO
Sand Wash Mining Co. c/o L. P. Anderle Myton, UT 84052	Sand Wash Nos., 3, 4, 6, secs. 28, 29, 33 T. 11 S., R. 18 E.	NO

Skyline Oil Co.
University Club Bldg.
Salt Lake City, UT 84111

Winnie C. Slaught
Arcadia, UT 84005

Sohio Petroleum Co.
1100 Penn Tower
Oklahoma City, OK 73118

Briant H. Stringham et al.
209 East 1st North
Vernal, UT 84078

Texaco Inc.
3350 Wilshire Blvd.
Los Angeles, CA 90005

Nick and Tom Theos
P.O. Box 447
Meeker, CO 81641

Clinton P. Townsend Estate
71 So. Mountain Ave.
Montclair, NJ 07042

Whittier College, Trustee
Whittier, CA 90608

Utah Colorado Oil Corp.
Wilson Snyder
2163 Elizabeth St.
Salt Lake City, UT 84106

Table II-4 Con't

Skyline oil shale properties,
Uinta Basin

NO

Slaught-Evans,
sec. 21, T. 4 S., R. 22 E.

NO

Mack, Castle, Earley Cliff,
secs. 22, 23, 27, 34, T. 9 S., R. 25 E.,
secs. 3, 4, 6, 7, T. 10 S., R. 25 E.,
secs. 6, 18, 19, T. 11 S., R. 25 E.,
secs. 25, 26, T. 10 S., R. 24 E.

NO

Denver, 4, 6, 8,
secs. 13, 24, 26, T. 9 S., R. 25 E.

NO

Texaco O.S.
secs. 16, 17, 20, 21, 22, 27, 28, 29,
32, 33, 34, 35, T. 12 S., R. 23 E.,
secs. 2, 3, 4, 5, 6, 8, 9, 20, 11,
15-22, 29, T. 13 S., R. 23 E.

NO

Alamo properties,
T. 10 S., R. 25 E.

NO

Shale Nos. 7, 8,
sec. 28, T. 9 S., R. 25 E.

NO

Takola 1-5, Denver, 3, 4, Madison,
secs. 25, 26, 35, 36, T. 9 S., R. 25 E.

NO

Union, Paraffine, Gasoline et al.,
T. 12 S., R. 25 E.

NO

Table II-4 Con't

	Utah Oil Shale Inc. 10 Exchange Pl. Salt Lake City, UT 84111 also: Utah Shale Land & Mineral Corp.	Keeler area, Ashton Chambers, Nebeker, Vernal, secs. 4, 5, 9, 16, 17, T. 13 S., R. 21 E., T. 13 S., R. 20 E.	NO
	Utah Parafine Oil & Wax Co. 163 So. Main St. Salt Lake City, UT 84111	Petroleum Mountain, T. 11 S., R. 8 E.	NO
Utah	Raddatz Corp. 1111 Walker Bank Bldg. Salt Lake City, UT 84111	Aetna, Ford, Ray, Mud Hollow, Kauffman et al. claims, unorganized mining district, secs. 1, 3, 4, T. 10 S., R. 6 E., sec. 31, T. 9 S., R. 7 E., T. 9 S. R 6 E.	NO
Wasatch	Amoco Production Co. Security Life Bldg. Denver, CO 80202	Polar-Sage claims	NO
	Thomas Q. Cannon, Investments 79 West 1st South Salt Lake City, UT 84111 also: 5340 Cottonwood Lane Salt Lake City, UT 84117	Ibex, Crude Oil placer claims, secs. 25, 26, T. 5 S., R. 11 W., southeast of Currant Peak, secs. 24, 25, 26, T. 9 S., R. 7 E., northeast of Soldier Summit	NO
	Raddatz Corp. 1111 Walker Bank Bldg. Salt Lake City, UT 84111	Vulcan, Victory, Oil Standard, secs. 26, 35, T. 9 S., R. 7 E., secs. 29, 30, 31, T. 9 S., R. 8 E., unorganized mining district, north of Soldier Summit	NO
	Utah Parafine Oil & Wax Co. 163 So. Main St. Salt Lake City, UT 84111	B.B. & B.B., Prince, T. 10 S., R. 8 E., Soldier Summit area	NO

Source: Carlton H. Stowe, Utah Mineral Industry Operator Directory 1979
(Salt Lake City, Utah : Utah Geological and Mineral Survey, June 1979)

Figure II-5

Active Oil Shale Operations, Eastern Uinta Basin, Utah

Table II-5

Oil Shale Retorting

Type

Description

1. Surface Retorting

The surface approach for converting the Kerogen in oil shale into crude requires that the shale be mined in either a surface or underground mine; be transported to the processing plants; and be crushed and fed into a retort heated to approximately 900° F. where the Kerogen is converted from a solid waxy material into a liquid. The liquid hydrocarbon is collected, hydro-treated to pipeline quality, and piped to a refinery for further processing. The spent shale is deposited in landfills.

A. Gas Combustion Process

The gas combustion process developed by the Bureau of Mines involves combustion of a portion of the gas formed in the retorting process to accomplish thermal decomposition. This process may be economically and efficiently conducted in the Cameron and Jones' vertical kiln which is presently under construction as an 18-foot diameter vertical cement kiln. An 18-foot retort is estimated to have a capacity of more than 2,000 tons of oil shale per day.

B. Union Oil Company Retort

The Union Oil Company retort burns the residual coke left on the rock after retorting as a source of process heat. The largest unit constructed to date had an average inside diameter of 13 feet and operated at an oil shale capacity in excess of 1,000 tons per day. This retort ran smoothly and automatically, requiring little operating labor.

C. TOSCO Retort

Indirect heating is utilized in The Oil Shale Corporation process or TOSCO retort as it is called. Pre-heated ceramic balls are introduced into a rotary kiln together with finely-ground shale and retorting occurs by solid-to-solid heat exchange. This process has been demonstrated in a 24 ton per day pilot plant having an inside diameter of 2 feet.

2. In Situ Retorting

The various in situ techniques, although not as well developed, require that a portion of the shale seam be fractured. A flame zone is then passed through the fractured material that retorts the shale in place. The liquid shale oil is collected and further processed in the same manner as in the surface technique. Problems inherent in the in situ technique include obtaining uniform fracturing, obtaining uniform heating as the flame zone moves through the fractured zone, and self-heating of the fracture. Several organizations have attempted to process shale in situ, including USBM, Sinclair Oil Co., Equity Oil Co., and Occidental Oil Co. Currently ERDA and Occidental Oil Co. have development programs in process.

3. Multimineral Recovery

Multimineral concepts, such as the Superior Oil Process, recover not only the oil from the oil shale but also recover the nahcolite, alumina, soda ash, and water. Only the spent shale is returned to the mine. The raw shale is crushed, pressed, screened and then is partially calcined in a kiln where a white film is deposited on the nahcolite particles. The shale and nahcolite particles are then passed through a feeder onto a belt conveyor where the particles are scanned with a computer-controlled laser scanner with an air blast separator. As the particles leave the conveyor belt the air blast is directed toward the nahcolite particles, changing their trajectory and separating the shale from the nahcolite. The crushed shale is placed in a circular grate retort where it is heated indirectly. The spent shale from the retort is processed to remove the alumina and soda ash.

Source: Alexander McRae, Janice L. Dudas, and Howard Rowland, Ed., The Energy Source Book (Germantown, Maryland: Apsen Systems Corp., 1977), pp. 263-265.

Cameron and Jones, Inc.

Oil Sands

Currently, there is no significant oil sand development in Utah. Table II-6 presents a summary of Utah's tar sand production and properties. An assessment study of Utah's oil shale and oil sands by Uintah Basin Association of Governments and Utah's Department of Energy summarizes the current industry status. There are currently no oil sand projects scheduled as contributing on-line commercialized plants to the synthetic fuels industry by 1990. However, there is a high degree of probability that some form of pilot and/or demonstration plant could be on-line by this time.

Currently, there are five oil sand projects that are under consideration for future development. These projects include:

- Rio Tintic Mining Company-Resource Unknown
- Great National Corporation-Sunnyside
- Sohio Petroleum-Asphalt Ridge
- University of Utah and Associates-Resource Unknown
- Sagad hoc Energy-Tar Sands Triangle 7

A summary of the known Oil sand recovery techniques are shown in Table II-7. These techniques include surface mining and underground mining methods.

Resource Development Requirements

Oil Shale

There are no specific energy resource requirements for starting up an oil shale operation. Table II-8 shows the expected production capacity for Utah's three oil shale projects. The plant capacity ranges from 2,000 barrels per day for the Geokinetics to 100,000 barrels per

Table II-6
Oil Sand Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production</u>
Carbon	R. R. Burgmeyer 25 La Solan Millbrae, CA 94030	Sunnyside Nos. 4, 6, 7, secs. 3, 10, T. 14 S., R. 14 E., Sunnyside area, Tidewell and Rideout district	NW
	B. R. Schonlau 19611 Mayall St. Northridge, CA 91324	Asphalt Nos. 1, 2, sec. 30, T. 13 S., R. 14 E., Sunnyside Nos. 4-7, secs, 3-10 T. 14 S., R. 14 E., Tidewell and Rideout district	NO
Grand	Ajax Building Corp. 3276 So. 3690 West Salt Lake City, UT 84120	Adams and Bryson pits, P. R. Springs area, State Survey No. 5958, Grand County school district	NO
Uintah	Sohio Petroleum Co. 1100 Penn Tower Oklahoma City, OK 73118	T. 4 S., R. 20, 21 E., Asphalt Ridge	NW
	Irene Wilson 201 Stonewall Rd. Berkeley, CA 94705	Wilson properties, sec. 5, T. 5 S., R. 21 E., west of Jensen	NO
Utah	W. A. Roennicke c/o Stl Louis Union Trust Co. Southwest corner of Broadway & Locust St. Louis, MO 63102	Kempton, Laura, More, Compton, Ottman, Malta et al	NW

Source: Carlton H. Stowe, Utah Mineral Industry Operator Directory 1979
(Salt Lake City, Utah: Utah Geological and Mineral Survey, June 1979).

Table II-7

Tar Sands Recovery Techniques

Type

Description

1. Surface Mining

The only commercial tar sands plant in operation is the Great Canadian Oil Sands (GCOS) plant, located north of Edmonton, Alberta, Canada. The facility began operations in 1967 and now produces roughly 50,000 barrels per calendar day of high quality synthetic crude oil from 130,000 tons per day of tar sands feed. Huge bucketwheel excavators strip the tar sands from the Athabasca into terraces 70 feet high.

Syncrude Canada, Ltd., is building a plant in the Athabasca deposit. Surface mining with large electric draglines will be employed.

As in recovering coal, surface mining is an economical recovery technique for deposits lying close to the surface with little or no overburden. But the cost of mining one cubic yard of overburden is about the same as mining one cubic yard of high grade ore. A general rule of thumb used for Canadian operations is that the ratio of overburden thickness to ore body thickness should not exceed one. Factors such as ore grade, overburden characteristics and ultimate product market value can affect this ratio.

Surface mining cleanup operations are accomplished with bulldozers, scrapers, and front-end loaders. In addition to the disposal of overburden and waste sand from the separation process, large amounts of waste water from above ground extraction facilities must be handled. The GCOS facility pumps approximately 24,000 gpm of slurry into holding ponds. Some of this water may be recycled, but much of it contains clay and sand which remain in suspension indefinitely.

2. Underground Mining

Very little experience has been gained in underground mining of tar sands, primarily because of the abundance of surface accessible deposits in Alberta. Conventional hardrock mining is not feasible, because of the structural makeup of tar sands deposits. It may be possible to modify conventional longwall mining techniques to recover tar sands.

On the other hand, hydraulic mining might be used. The technique has been used quite successfully for underground mining of uranium ore, and is now being tested with tar sands in Southern California. A capsule containing a high pressure nozzle, a slurry pump, and piping is lowered through

Table II-7 Con't

the tar sands zone into the underlying formation. The nozzle directs a stream of water against the tar sands deposit, breaking the material into small pieces which are then entrained in the waste water as a slurry. The slurry drains into the sump in the underlying zone and from there it is pumped to the surface for above-ground processing.

Source: Alexander McRae, Janice L. Dudas, and Howard Rowland, Ed.,
The Energy Source Book (Germantown, Maryland: Aspen Systems
Corp., 1977), p. 277.

Table II-8

Energy Production and Water Requirements
for Utah's Oil Shale Developments

(1979)

<u>Oil Shale Project</u>	<u>Production Capacity (Barrels Per Day)</u>	<u>Water Requirements (Acre feet Per Year)</u>
White River Shale	100,000	13,000
TOSCO	47,000	9,000 ^a
Geokinetics	2,000	0 ^b

- a. Possible to reduce water consumption by 20 percent with further technological improvements.
- b. Geokinetics method of oil shale production requires no water. In fact, water is produced at about 50 percent of the total liquids recovered from their in-situ retorts.

Source: Uintah Basin Association of Governments and Utah State Energy office, An Assessment of Oil Shale and Oil Sands Development In The State of Utah (Uintah Basin Association of Governments and Utah Department of Energy, October 1979), pp. 13, 14, 23, 24, and 30.

day for the White River Shale project. In 1976, some financial and economic analysis was performed that showed the profit margins given various production costs. (See Table II-9 and Figure II-6). As a rule of thumb, to produce one barrel of oil shale crude it takes one to two tons of oil shale or about 100 square feet of oil shale land.

Water requirements for Utah's oil shale projects are shown in Table II-8. Geokinetics in situ processing method does not require any water for processing. In fact, water becomes a by-product of this technology. Tosco's production requires 5.22 acre feet per year to produce 1 barrel of oil per day for the year while the White River Shale project requires 47 percent more water or 7.69 acre feet per year to produce one barrel of oil per day for the year.

The waste disposal systems for oil shale projects generally follow filling of canyons or valleys if a retorting method is used for production and for the in situ process the spent shale remains in the underground mine and therefore requires no disposal program. (See Table II-10.) Figure II-7 shows the various by-products of a 50,000 barrel per day oil shale processing system. The byproducts include crude oil, cole, ammonia, sulfur and low BTU gas.

The air shed requirements for an oil shale project will be the same for any other energy development project. Appendix A contains a summary of federal and state air quality requirements by the White River Shale Project.

Oil Sands

Energy resource and water requirements for oil sand developments are relatively uncertain at this time. Currently, there are no oil sand

Table II-9

ESTIMATED OIL SHALE PRODUCTION COST^a
(1976)

<u>Process</u>	<u>Investment Cost (dollars/barrel/day)</u>	<u>Operating Cost (dollars/barrel)</u>	<u>Selling Price (15% CDF,^c 100% Equity) (dollars/barrel)</u>
Modified in situ	5,000-7,000	3.50-5.00	8.00-11.00
Surface retorting	14,000-23,000	4.00-5.00	16.00-25.00
Multimineral ^b	7,000-9,000	2.75-4.00	9.00-12.00

- a. The oil produced by these methods may be pre-refined to a quality comparable with Arabian crudes for an additional \$1 to \$4 per barrel.
- b. Superior Oil Process is an example of multimineral shale treatment. (See Figures VI-14 and VI-15)
- c. See Figure VI-16 for selling prices at different discounted cash flow (DCF) rates.

Source: Dr. Philip White Statement on ERDA's R&D Program in Oil Shale, before the Subcommittee on Minerals, Materials, and Fuels of the Senate Committee on Interior and Insular Affairs on November 30, 1976.

Figure II-6

REQUIRED SHALE OIL SELLING PRICE AS FUNCTION OF
DISCOUNTED CASH FLOW

(1976)

Source: Proposed Synthetic Fuels Commercial Demonstration Program Fact Book, ERDA, March 1976.

Table II-10
Waste Disposal Methods
for Utah's Oil Shale Developments
(1979)

<u>Oil Shale Project</u>	<u>Location and Method</u>
White River Shale	Southam Canyon- Processed shale will be brought from retorting area by conveyor to a loading truck bin. From there trucks will move the spent shale to the disposal area where they will dump and compact the material in layers. Bulldozers will complete the sculpturing and contouring of the pile so that it blends in with the surrounding topography.
TOSCO	Processed shale is transported to a nearby canyon or valley where it is spread and compacted in terraced embankments. Extensive Revegetation studies have been carried out.
Geokinetics	For in-situ processing, spent shale remains underground and, therefore, requires no disposal program.

Source: Uintah Basin Association of Governments and Utah State Energy office, An Assessment of Oil Shale and Oil Sands Development in the State of Utah (Uintah Basin Association of Governments and Utah Department of Energy, October 1979), pp. 17, 18, 26, and 31.

Figure II-7

ENERGY BALANCE FOR A
50,000 BARREL PER DAY OIL SHALE PROCESSING SYSTEM

Source: Process Evaluation Group, Bureau of Mines, Morgantown, W. Virginia

Table II-11

Major Impacts of
Oil Shale and Oil Sand Developments

<u>Major Impacts</u>	<u>Nature of Effect</u>	
	<u>Direct</u>	<u>Indirect</u>
Physical Resources		
Land		
Surface Disturbance	X	
Erosion	X	
Spent Shale	X	
Chemical Waste	X	
Trash and Other	X	
Soil	X	
Forage	X	
Timber	X	
Other Minerals	X	
Landscape, Esthetics	X	
Water		
Water Quality	X	X
Water Supply and Aquifers	X	
Subsidence Effects		X
Air		
Dust	X	
Plant Emissions	X	
Recreation		
Disturb Use		X
Wilderness		X
Fish and Wildlife		
Habitat	X	X
Fishing		X
Hunting		X
Socio-economic		
Cultural		
Historic Sites		X
Archeological Sites	X	
Social Living Patterns		X

Table II-11, Cont.

	<u>Nature of Effect</u>	
	<u>Direct</u>	<u>Indirect</u>
Population		
Immigration		X
Concentration		X
Economic		
Jobs	X	
Income	X	
Capital Flow	X	
Health and Safety		
Plant Hazzard	X	
Other Accident	X	
Pipeline and Transportation	X	
Government		
Services	X	
Taxes	X	
Title Conflicts		X
State and Other		X

Source: Project Independence, Task Force Report, Future Role of Oil Shale Prospects and Constraints, 1974, pp. 53 and 54.

projects scheduled for development in Utah that could be identified as being a contributing component to the synthetic fuels industry by 1990.⁸ The air quality requirements are the same as presented in Appendix A for an oil sands project.

The Air quality standards will have an impact on controlling the dust generated which adds to the suspended particulates in the air by construction, transportation, and processing activities. In addition to the dust, gaseous emissions released from the plant, mining activities, reclamation equipment and employees vehicles will also contribute to the air pollution problem.

Potential Environmental and Socio-Economic Impacts

The major impacts both direct and indirect which are related to both oil shale and oil sand developments are presented in Table II-11. The major impacts are categorized under the following headings: Physical resources--land, water, air, recreation, fish and wildlife, and Socio-Economic Resources--cultural, social living patterns, population, economic, health and safety, and government. Appendix B contains a detailed qualitative summary of these impacts. In summary, by using the Colony Oil Shale Development of Colorado as an example, the physical impact of producing one barrel of oil shale will use:

- 2 to 6 barrels of water
- 1 to 2 tons of oil shale
- 100 square feet of land

One barrel of oil shale will produce:

- One-third of a pound of airborne dust
- 2.5 pounds of polluting gases

- 2 to 5 gallons of contaminated water and
- 1 to 1.5 tons of spent shale ⁹

Transportation Tradeoffs

The basic means of transporting oil shale for processing will be truck or rail vehicle, the basic means of transportation of the oil shale crude will be by existing and new pipelines. The following summarizes the potential markets by oil shale development:

<u>Project</u>	<u>Potential Market Areas</u>
White River Shale	<ul style="list-style-type: none"> • Wasatch Front • Los Angeles • Midwest (probably most promising)
Tosco	<ul style="list-style-type: none"> • Salt Lake via Chevron pipelines • Colorado via Amoco pipeline • Pure Oil Pipeline-140 miles south at Lisbon, UT • Proposed Colony Oil Shale Pipeline • By-Products to be Shipped by truck
Geokinetics	<ul style="list-style-type: none"> • Salt Lake City Refineries • Roosevelt, Utah Refineries • Fruits, Colorado Refineries • Proposed Pipeline linkage to existing • Common Carrier Lines to Salt Lake City. • Currently using tanker trucks for R & D output. ¹⁰

Future detailed information can be found in Appendices C and D which contain bibliographies of oil shale and oil sands developments.

Section II - Footnotes

¹ Utah Basin Association of Governments and Utah Energy Office, An Assessment of Oil Shale and Oil Sands Development In The State of Utah (Utah Basin Association of Governments and Utah Department of Energy, October 1979), p.3.

² Ibid., P.33.

³ Ibid., P.33.

⁴ U.S. Department of Interior. Project Independence Task Force Report, Future Role of Oil Shale: Prospects and Constraints, 1974, p, 105.

⁵ Ibid., pp. 5 and 6.

⁶ Ibid., p. 6

⁷ Ibid., pp. 37 and 38.

⁸ Ibid., p. 37

⁹ U.S. Environmental Protection Agency; Office of Research and Development, Oil Shale and The Environment, October 1977, p. 19.

¹⁰ Op Cit., pp. 11, 22, 23, 29 and 30.

SECTION III

GEOHERMAL RESOURCES IN UTAH

Geothermal energy resources, which is the internal heat of the earth, is one of the largest sources of energy available to man.¹ Geothermal energy is contributing only in a limited way to the U.S. energy situation with development of the Geysers in California. However, there are several proposed geothermal developments planned including at least the following:

<u>State</u>	<u>Geothermal Field</u>
California	Brawley East Mesa Heber
Utah	Roosevelt
New Mexico	Caldera

(See Figure III-1). Figure III-2 shows the extensiveness of known and potential geothermal resource areas in the United States.

Resource Potential and Location

The U.S. Geological survey and the State of Utah have been in the process of locating and examining geothermal resources in the state. Figure III-3 shows the geothermal resources in Utah by County. There is a definite trend of the emergence of the geothermal resource along the Wasatch Front, along the southwest portion of the state, and also in the Uintah Basin. Tables III-1 and III-2 and Figure III-4 present a

Figure III-1

GEOHERMAL EXPLORATION IN THE UNITED STATES

LEGEND

- * Developed Geothermal Field
- Areas Undergoing Evaluation for Development
- ▲ Deep Exploratory Drill Hole, 1968-75
- Drilling as Part of Research Program
- Utilization of Low-Enthalpy Fluids

Sources: James B. Koenig, *et al*, "Exploration and Development of Geothermal Resources in the United States," Second United Nations Symposium for the Development and Utilization of Geothermal Resources, San Francisco, May 1975.

Figure III-2

KGRA AND POTENTIAL GEOTHERMAL RESOURCE AREAS
IN THE UNITED STATES

Source: Comptroller General of the United States, "Problems in Identifying, Developing and Using Geothermal Resources," March 6, 1975.

Table III-1

Areas favorable for discovery and development of local
sources of low-temperature (<90°C) geothermal water in UTAH

Area number and name	Wells considered			Thermal springs		Thermal gradients (°C/km)	Equilibra- tion. temp. (°C)
	No.	Depths (m)	Temp. (°C)	No.	Temp. (°C)		
1. Cache Valley	19 5	60-300 300-833	20-30 30-49	1	31	35-97	---
2. Wasatch Front	9 135	<300 300	35-74 20-35	17 23	35-58 20-35	27-380	---
3. Tooele and Skull Valleys	14	<300	20-35	13	20-35	---	---
4. Bonneville Salt Flats	2 10	366, 499 300	35 20-35	1	~30	75, 145	---
5. Uinta Basin	11 3	<390 300	43-56 20-35	--	---	38	---
6. Central Sevier River - Sanpete Valleys	0	(<1 km)	---	3 5	>35 20-35	---	---
7. Abraham Hot Spring - Newcastle	6 63	<300 300	35-67 20-35	7	20-36	Reportedly high	---
8. Beaver Valley	3	---	20-35	1	>30	---	---

Table III-1 Cont.

Dissolved Solids (mg/L)	Remarks
---	Deep circulation in fault zones. Mostly Quaternary aquifers; some wells tap Tertiary Salt Lake Formation. Shallow thermal waters restricted to valley margins. Highest temperature (49°C) encountered in 833 m oil test well. References: 29, 63
1,000-45,000	Deep circulation in fault zones. Most wells in Lake Bonneville and older Quaternary deposits. Thermal springs have high yields of moderately saline to briny water. Reference: 29
sl. to mod. Saline	Deep circulation in fault zones. Wells in Lake Bonneville and older Quaternary deposits. Favorable sites along valley margins. Reference: 29
Briny	Deep circulation in fault zones. Wells in Lake Bonneville and older Quaternary deposits. Reference: 29
Briny Fresh-sl. saline	Deep circulation in Duchesne fault zone. Includes Ashley Valley oil and gas field. Reference: 29
<2,000-5,000	Deep circulation in fault zones. Includes Monroe-Red Hill and Joseph KGRA's. Reference: 29
1,000-5,000	Deep circulation with possible cooling magma at depth. Includes Crater Springs, Newcastle Meadow-Hatton, Cove Fort, Roosevelt, Thermo, and Lund KGRA's. References: 29, 78
---	Deep circulation in fault zones. References: 29, 63

Table III-1 Cont.

Comments	Wellhead thermal energy (10^{18} J)	Wellhead available work (10^{18} J)	Electrical energy (MW_e for 30 yr)
Area of H_2S gas seeps, sulfur and sinter deposits, but no springs. Three wells 582 to 2226 m deep; maximum temperature $179^\circ C$ at 2226 m. Reservoir temperatures are measurements from one well and could be higher at other locations.	4.0	0.78	330
Seven wells in a 6-km^2 area and ranging in depth from 382 to 2234 m are capable of producing over 4.5×10^5 kg/hr total mass flow at $260^\circ C$. A $55 MW_e$ plant is planned. Minimum and most likely temperatures are recorded temperatures at about 380 and 1870 m, respectively. Springs are inactive; extensive sinter deposits along a 4.8-km trend.	8.0	2.3	970

Source: U.S. Department of Interior and U.S. Department of Energy. Assessment of Geothermal Resources of the United States - 1978, Geological Survey Circular 790, pp.120-121.

Table III-2

No.	Name of area	Latitude (°N) Longitude (°W)	Estimates of reservoir temperature (°C)	Mean reservoir temperature (°C)	Mean reservoir volume (km ³)	Mean reservoir thermal energy (10 ¹⁸ J)
208	Cove Fort-Sulphurdale	38 36 112 33	150 170 180	167 ± 6	39 ± 10	16.0 ± 4.1
209	Roosevelt Hot Spring (McKean)	38 30.0 112 50.9	243 (M) 269 (M) 284 (I)	265 ± 8	47 ± 20	20 ± 13

*Total of wellhead thermal energy, available work, and electrical energy exclude National Parks.

Source: U.S. Department of Interior and U.S. Department of Energy. Assessment of Geothermal Resources of The United States - 1978, Geological Survey Circular 790, pp. 56 and 57.

Figure III-4

DETAILED MAP OF UTAH'S GEOTHERMAL RESOURCES

Source: U.S. Department of Interior and U.S. Department of Energy.
Assessment of Geothermal Resources of the United States - 1978,
Geological Circular 790, MAP ON WESTERN UNITED STATES.

Figure III-4 Cont.

Hydrothermal conv. systems $\geq 90^{\circ}\text{C}$. in U.S. Geological Survey Circular 790). Supporting data from USGS computer file GEOTHERM are published in Open-File Report 78-058, available from Open-File Services Section, Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225

Hydrothermal convection systems, showing reservoir thermal energy in units of 10^6 joules

Vapor dominated systems

216A 1 10

40 10 100

Hot water systems $> 150^{\circ}\text{C}$

146 1 10

64A 10 100

216 > 100

Hot water systems $< 150^{\circ}\text{C}$

30 < 1

50 1 10

117 10 100

102 > 100

Identifying numbers refer to individual hydrothermal convection systems for which thermal energies are listed in USGS Circular 790. The number of circles (1 to 4) symbolizes the thermal energy of each system and is not representative of the area of the system.

Igneous Systems

See Smith, R.L., and Shaw, H.R., Igneous related geothermal systems, in U.S. Geological Survey Circular 790. Complete listing of location, age, composition, size, and thermal energy is given in USGS Open-File Report 78-925, available from Open-File Services Section, Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver CO 80225.

Volcanic systems showing estimated thermal energy in units of 10^6 joules. Most are silica and thought to have a magma chamber within 10 km of the surface.

014 < 100

004 100 1000

121 1000 10,000

1 > 10,000

Volcanic system for which no thermal estimate has been made. Most are andesitic or basaltic and are assumed to have no magma chamber within 10 km of the surface. Silicic systems are included where data are inadequate to allow thermal estimates.

Basaltic lava field younger than 10,000 years, showing major vent.

Identifying letters and numbers refer to igneous systems listed in USGS Circular 790 and USGS Open-File Report 78-925.

Low Temperature Geothermal Waters

See Samuel, I.A., Occurrence of low-temperature geothermal waters in the United States, in U.S. Geological Survey Circular 790.

Thermal springs, generally $\geq 20^{\circ}\text{C}$
 ○ Surface temperature not known
 ⊙ Surface temperature $\leq 50^{\circ}\text{C}$
 ⊕ Surface temperature $> 50^{\circ}\text{C}$

Area of significant lateral extent favorable for discovery and development of local sources of low temperature ($< 90^{\circ}\text{C}$) geothermal water. Identifying number refers to area listed in USGS Circular 790. Areas are defined by I.A. Samuel (USGS) and Duncan Foley (MSU/URR) in cooperation with state agencies on the basis of thermal springs, wells, and geologic settings generally favorable for recovery of thermal water. Existing knowledge does not in general permit the inference that thermal water may be found everywhere within the depicted areas, nor do the boundaries represent certain knowledge of the areal extent of the geothermal systems.

* Well or test hole in which thermal gradient and temperature at depths less than 1 km represent a local shallow geothermal anomaly: shown only outside shaded areas described above.

Regional Heat Flow

See Sass, I.H., and Lachenbruch, A.H., Heat flow and conduction dominated thermal regimes, in U.S. Geological Survey Circular 790.

Generalized contour of regional heat flow in milliwatts/m². Dashed contour indicates area of less certain control.

Published regional heat flow datum in milliwatts/m².

Unpublished USGS regional heat flow datum. Numerical value not given but used for drawing generalized contours.

Known Geothermal Resources Area (KGRA)

National Park or selected National Monument

Selected cities
 ■ Population greater than 100,000
 ■ Population less than 100,000

Interstate highway

summary of the geothermal resources including the temperature of the wells, thermal springs and reservoirs. A forecast of the electrical energy derived from geothermal energy shows 880 Me for 30 years for the Cove Fort-Sulphurdale area and 970 Me for 30 years in the Roosevelt Hot Spring (McKean) area.

Federal and State geothermal leases in Utah are shown by county in Tables III-3 through III-5. Holders of large Federal active noncompetitive geothermal leases include: Agri-Empire, Atlantic Richfield, Brush Wellman Inc., Aminoil USA, Chevron USA, Inc., C.L. Hunt et al, Pacific Energy and Phillips Petroleum. Lease holders of large federally active competitive leases include: Phillips Petroleum Co, and Geothermal Resources International. The third classification of geothermal leases are the leases issued by the State of Utah. Large lease holders of this group include: Phillips Petroleum, C.L. Soulding, and R.E. Puckett.

The Energy Sourcebook summarizes the exploration and assessment of geothermal energy as follows:

Many of the exploration methods used in the petroleum and mining industries are also used for locating and assessing geothermal deposits. Normally, these methods include geologic examinations, fluid geochemistry and geophysics. Exploration for geothermal resources begins with the selection of prospective areas by geological mapping and data analysis. This is often followed by geochemical analysis of water from the hot springs, fumaroles, and other surface manifestations of geothermal energy. Such geochemical analysis provide estimates of the temperature of water in the subsurface reservoir. Usually, if geological and geochemical tests indicate reasonable prospect in an area, geophysical surveys are made. A geophysical survey estimates the properties and structures of subsurface rocks by gathering physical data from instruments placed at the surface. Several types of geophysical surveys are used in geothermal exploration.

Table III-3

FEDERAL ACTIVE NONCOMPETITIVE GEOTHERMAL LEASES IN UTAH
(as of 3/14/79)

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION
BEAVER		
Agri-Empire	11,890.76(3)	T30S, R13W
Amax Exploration	9,112.33(6)	T27 & 28S, R7, 12 & 13W
Atlantic Richfield	12,325.24(7)	T26-28S, R9-11W
M. S. Fisher	5,721.26(3)	T26-27S, R9-10W (One lease partly in Millard County)
C. J. Folmar	7,522.54(5)	T26 & 27S, R8 & 10W (One lease partly in Millard County)
Geothermal Exploration Co.	2,542.00(2)	T27S, R9 & 11W
Geothermal Power Corp.	640.00(1)	T26S, R8W
Geothermal Resources Int'l.	2,244.33(1)	T30S, R11W
N. B. Gillette & E. V. Ciancanelli	7,628.26(4)	T26S, R7 & 8W (One lease partly in Millard County)
N. B. Gillette J. Quinn & E. V. Ciancanelli	1,855.23(1)	T26S, R7W (Lease partly in Millard County)
C. L. Golding	2,320.43(1)	T26S, R10W (Lease partly in Millard County)
C. L. Hunt et al	7,916.28(5)	T26S, R6 & 7W; T30S, R9W
C. L. Hunt et al	6,555.66(3)	T30 & 31S, R10W (Also partly in Iron County)
N. B. Hunt	5,699.76(4)	T26S, R7W
M. F. Justice, Jr.	2,182.24(1)	T26 & 27S, R8W

Source: Federal Leases, Utah Hydrothermal Commercialization Baseline - June, 1979.

Table III-3 Con't.

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION
<u>IRON</u>		
Agri-Empire	7,263.76(3)	T31 & 32S, R13 & 14W
Amax Exploration	6,653.68(6)	T31S, R11 & 12W
Geothermal Exploration Co.	1,920.00(1)	T31S, R11W
Geothermal Kinetics Inc.	3,083.36(2)	T31 & 32S, R13 & 14W
Geothermal Resources Int'l.	2,400.90(1)	T31S, R11 & 12W
C. L. Golding	5,315.05(5)	T32 & 34S, R14, 16 & 17W
C. L. Hunt et al	1,403.88(1)	T31S, R11W
O'Brien Resources	2,560.00(1)	T31S, R11W
Republic Geothermal	6,115.86(4)	T31 & 32S, R12-14W
Supron Energy Corp.	1,920.00(1)	T31S, R12W
Thermex Co.	2,177.48(1)	T31S, R11W
<u>JUAB</u>		
Brush Wellman Inc.	20,363.52(9)	T12 & 13S, R12 & 13W
Earth Power Corp.	1,631.24(1)	T11S, R14W
Gulf Mineral Resources	3,852.84(2)	T14 & 15S, R8W (One lease partly in Millard County)
Pacific Energy Corp.	1,907.96(1)	T13 & 14S, R8W
Thermal Resources Inc.	2,520.00(1)	T30S, R9W

Table III-3 Cont.

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION
Union Oil of California	640.00(1)	T14S, R8 & 9W
U. S. Geothermal Corp.	2,077.00(1)	T11S, R14W
H. L. Wood	5,767.89(3)	T13 & 14S, R7 & 8W
<u>MILLARD</u>		
Amax Exploration	2,925.01(4)	T22-25S, R6 & 7W
Aminoil USA	10,107.75(5)	T21-23S, R6W
Amoco Production Co.	1,923.19(1)	T25S, R10W
A. S. Bowers	2,520.00(3)	T25S, R8 & 9W
Chevron USA, Inc.	13,494.08(8)	T23-25S, R6-9W
Earth Power Corp.	4,079.66(3)	T19, 22 & 23S, R6-8W
Flying Diamond Oil Corp.	3,840.00(2)	T24S, R9W
- Geothermal Exploration Co.	3,194.52(2)	T25 & 26S, R7W
N. B. Gillette & E. V. Ciancaneili	7,294.06(3)	T25S, R8 & 9W
C. L. Hunt et al	28,152.03(14)	T23-25S, R7-9W
N. B. Hunt	1,263.00(2)	T25 & 26S, R6 & 7W
N. K. Hunt	1,280.00(2)	T26, 27 & 29S, R6 & 7W (One lease partly in Beaver County)
O'Brien Resources & Exploration	5,080.00(2)	T23S, R8W

Table III-3 Con't

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION
O'Brien Resources	2,039.00(1)	T24S, R8W
Pacific Energy	13,614.59(8)	T20 & 21S, R8 & 9W
Phillips Petroleum	12,242.16(8)	T24-26S, R6 & 7W
Roosevelt Hot Springs Corp.	1,520.00(1)	T25S, R10W
W. A. Stevenson	1,560.00(2)	T23S, R6W; T24S, R8W
Thermal Resources, Inc.	3,675.95(2)	T22S, R6W
Thermal Power Co. of Utah	3,950.99(2)	T24S, R7W
Union Oil of California	591.84(1)	T26S, R6W (Lease partly in Beaver County)
U. S. Geothermal Corp.	3,109.60(2)	T23S, R7 & 8W
H. L. Wood	1,922.55(1)	T15S, R7 & 8W
<u>SEVIER</u>		
Steam Corp. of America	1,469.42(1)	T25 & 26S, R3W
Thermex Co.	707.00(1)	T26S, R3W
Union Oil of California	4,566.06(3)	T25S, R3 & 4W

Table III-4

FEDERAL ACTIVE COMPETITIVE GEOTHERMAL LEASES - UTAH
(1979)

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	KGRA/LOCATION	DATE ISSUED & (COST/ACRE)
BEAVER			
Bountiful Municipal Corp.	40.00(1)	Roosevelt Hot Springs KGRA, T27S, R9W	11/1/74 (\$3.00)
Geothermal Resources Int'l.	1,920.00(1)	Thermo Hot Springs KGRA; T30S, R11W	5/1/76(\$3.25)
Getty Oil	1,920.00(1)	Roosevelt Hot Springs KGRA; T27S, R9W	11/1/74(\$12.50)
W. H. Hunt	1,730.88(3)	Cove Fort - Sulphurdale KGRA; T26S, R6, 7 & 9W	6/1/78(\$111.11) & (2) N. A.
Phillips Petroleum Co.	17,690.97(10)	Roosevelt Hot Springs KGRA; T26 & 27S, R9W	10/1/74(\$5.11 - 128.06) & (1) N. A.
Republic Geothermal	1,200.58(1)	Thermo Hot Springs KGRA; T30S, R12W	5/1/76(\$5.12)
Supron Energy Corp.	3,563.21(2)	Thermo Hot Springs KGRA; T30S, R12W	5/1/76(\$3.37 & 7.28)
Thermex Co.	3,840.00(2)	Thermo Hot Springs KGRA; T30S, R11W	9/1/75(\$2.11)
Union Oil of California	1,600.00(1)	Roosevelt Hot Springs KGRA; T26S, R9W	11/1/74(\$20.31)
Union Oil of California	1,969.72(2)	Cove Fort - Sulphurdale KGRA; T26S, R6 & 7W	5/1/75(\$44.83) & 6/1/75(\$171.42)
Union Oil of California	960.00(1) 2,504.65(2)	KGRA N. A.; T26S, R9W KGRA N. A.; T26S, R6&7W	N. A. N. A.
Western Geothermal	1,002.19(1)	Thermo Hot Springs KGRA; T30S, R12W	9/1/75(\$5.06)

Source: Federal Leases, Utah Hydrothermal Commercialization Baseline -- June 1979

Table III-4 Con't

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	KGRA/LOCATION	DATE ISSUED & (COST/ACRE)
<u>IRON</u>			
C. L. Golding	3,360.00(2)	Lund KGRA; T32S, R14W	5/1/76(\$1.77)
Supron Energy Corp.	1,924.58(1)	Thermo Hot Springs KGRA; T31S, R12W	5/1/76(\$5.28)
Union Oil of California	1,830.56(1)	Newcastle KGRA; T36S, R1W	11/1/77(\$35.56)
<u>JUAB</u>			
Chevron USA, Inc.	2,582.88(1)	Crater Springs KGRA: T14S, R8 & 9W	5/1/76(\$3.57)
Geothermal Resources Int'l.	12,358.25(5)	Crater Springs KGRA; T13 & 14S, R8 & 9W	5/1/76(\$3.25)
<u>MILLARD</u>			
American Geological Enterprises Inc.	7,579.19(3)	Cove Fort - Sulphurdale KGRA; T24 & 25S, R6 & 7W	5/1/75(\$1.04, 3.04 & 3.04)
C. L. Hunt et al	2,840.00(2)	Cove Fort - Sulphurdale KGRA; T24S, R7W	12/1/77(\$156.5 & 12.12)
Union Oil of California	1,405.96(1)	Cove Fort - Sulphurdale KGRA; T22S, R6W	N. A.
Union Oil of California	1,405.96(1)	Meadow Hatton KGRA; T22S, R6W	N. A.
Union Oil of California	6,146.13(4)	Cove Fort - Sulphurdale KGRA; T25 & 26S, R6W	6/1/75(\$75.67 361.83)
Union Oil of California	1,204.92(2)	Cove Fort - Sulphurdale KGRA; T25 & 26S, R7W	N. A.

Table III-4 Con't

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	KGRA/LOCATION	DATE ISSUED & (COST/ACRE)
<u>SEVIER</u>			
Aminoil USA, Inc.	4,067.46(2)	Monroe-Joseph KGRA; T25 & 26S, R3W	1/1/78(\$2.26 & 2.58)
Union Oil of California	2,572.32(2)	Monroe-Joseph KGRA; T25S, R4W	11/1/77(\$41.14) & N. A.

Table III-5

SUMMARY OF BIDDING HISTORY FOR COMPETITIVE GEOTHERMAL LEASE
 SALES ON FEDERAL LANDS - UTAH
 (Source USGS ADP File - Format K-4)

COUNTY	KGRA	OFFERED	(INC. REOFFERS)		LEASES ISSUED		AVG. \$/ ACRE
		SALES	TRACTS	ACREAGE	NUMBER	ACREAGE	
BEAVER & MILLARD	Cove Fort- Sulphurdale	3	14	27,201	12	23,406	135.49
BEAVER	Roosevelt Hot Springs	3	15	25,871	14	24,681	35.78
BEAVER & IRON	Thermo Hot Springs	4	21	36,457	8	13,450	4.79
IRON	Lund	2	4	6,720	2	3,360	1.77
	Newcastle	1	1	1,831	1	1,831	
JUAB	Crater Springs	2	7	15,441	6	15,001	3.31
MILLARD	Meadow- Hatton	1	1	1,406	1	1,406	16.28
SEVIER	Monroe- Joseph	4	11	20,294	5	7,260	16.36
TOTAL		20	74	135,221	49	90,494	48.43

Resource Technology, Development and Production Status.

There are three primary types of geothermal systems: hydrothermal-convection, vapor-dominated and liquid-dominated systems. The hydrothermal-convection system transfers heat from a deeper endogenous source (magma) by the circulation of water or a vapor. The temperature for this system centers around 240° C. The vapor dominated system converts the pressure controlled by a vapor rather than a liquid. The system produces a saturated or slightly superheated steam which contains little or no liquid water and a small percentage of gases including CO₂ and H₂S. This system also has a temperature around 240° C. The third geothermal system, liquid dominated, transfers heat from deep sources of hot water to a geothermal reservoir at depths shallow enough to be tapped by drilled holes. Most of the liquid-dominated systems occur as hot springs, although other types exist. Hot water convection systems have been arbitrarily divided into three temperature ranges according to their potential end use:

- Above 150° C. for generation of electricity.
- 90° C. to 150° C. for space and process heating.
- Below 90° C. for local use where better energy sources do not exist.³

There are several different survey methods for locating geothermal energy. (See Table III-6.) These survey methods include: airborne, gravity magnetic, passive seismic, geologic and hydrologic and geochemical, and heat flow surveys methods.

Table III-6

State Geothermal Leases In Utah
(1980)

COUNTY	SIZE, ACRES & (NO. OF LEASES)	LOCATION	DATE ISSUED
BEAVER	46,042.00 (63)		
Amax Exporation	4,198.31 (6)	T26-30S, R7, 9, 11 & 13W	Various
American Oil Shale	1,920.22 (3)	T26S, R9W	8/6/73
Atlantic Richfield	80.00 (1)	T26S, R10W	2/13/79
R. C. Barr	1,238.57 (3)	T26, 30S, R7, 9W	4/25/77, 5/9/77
J. E. Blankenship	56.77 (1)	T26S, R8W	2/7/77
M. Bradshaw	130.32 (3)	T27, 28S, R9W	6/10/74, 2/3/75, 10/26/76
W. O. Darley	600.00 (1)	T27S, R9W	3/10/75
Davon Inc.	621.18 (1)	T26S, R8W	12/17/73
C. J. Folmar	2,672.52 (3)	T26, 28, 29S, R7, 9, 14W	1/12/76, 2/13/79
M. F. Justice, Jr.	2,464.16 (5)	T26-28S, R7, 9, 11W	7/15/74, 2/23/76, 3/8/76
S. V. McCormick	2,052.66 (3)	T27, 28, 30S, R12, 13W	8/6/73, 6/19/78
McCulloch Geothermal	80.00 (1)	T26S, R10W	2/3/79
S. L. McGarry	3,549.84 (3)	T26, 28S, R8W	5/20/74, 4/7/75
C. A. Marks	361.24 (1)	T27S, R8W	5/27/75
M. S. Papulak	2,241.36 (4)	T27-30S, R10, 17W	4/25/77, 5/9/77, 5/15/78, 2/13/79
Phillips Petroleum	13,462.77 (2)	T26, 27, 29, 30S, R10-13, 15, 16W	8/6/73, 8/1/75
W. A. Stevenson	2,610.11 (6)	T26, 27, 30S, R8, 10, 11W	8/6/73, 10/1/73, 10/3/77
Supron Co.	640.00 (1)	T29S, R12W	12/20/76
Thermal Power Co. of UT	5,052.25 (4)	T26, 27, 30, 31W, R9, 11, 12W	8/6/73
Thermogenics	90.00 (1)	T27S, R9W	5/3/78
A. B. Thomas & C.D. Shurtleff	640.00 (1)	T29S, R16W	1/30/78
Frederick E. Payne	1280.00 (2)	T30S R9W	8/9/79

Source: State Leases - Utah Geothermal Commercialization Project. Midterm Report - July 1979
Semi-Annual Report - Jan. 1980

Table III-6 Con't

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION	DATE ISSUED
BOX ELDER	3,303.00 (7)		
Robert Feinstein	615.00 (1)	T8N, R7W	4/30/79
Diane Katz	2,447.00 (8)	T7, 8N, R7, 8W	4/30/79, 9/14/79
R. E. Puckett	640.56 (1)	T9N, R4W	12/3/73
IRON	55,146.00 (47)		
Amax Exploration Inc.	622.80 (1)	T32S, R12W	4/18/77
R. C. Barr	680.00 (2)	T31S, R10, 11W	4/25/77
J. W. Covello	5,453.28 (6)	T32-34S, R13-17W	10/1/73, 7/15/74
Earth Power	766.44 (1)	T31S, R11W	8/9/76
Geothermal Kinetics Inc.	8,233.12 (5)	T33, 34S, R15-17W	12/22/75, 2/2/76
C. L. Golding	12,338.55 (10)	T31, 32, 34-36S, R13-16W	7/15/74, 11/11/74, 11/12/75, 2/9/76 2/23/76
M. F. Justice Jr.	4,348.29 (4)	T35, 36S, R14-16W	2/23/76
J. A. Murphy Jr.	2,167.48 (1)	T31S, R14W	7/1/74
Phillips Petroleum Co.	8,910.52 (5)	T31, 32S, R12, 14, 15, 16W	8/6/73, 6/23/75, 6/30/75, 8/1/75
W. A. Stevenson	320.00 (1)	T31S, R13W	4/18/77
Supron Co.	743.05 (1)	T31S, R7W	5/3/77
Thermal Power Co. of UT	3,202.52 (3)	T30 & 31S, R11-13W	8/6/73
U.V. Industries Inc.	6,259.02 (7)	T34-36S, R15-17W	2/23/76
JUAB	35,771.00 (29)		
American Oil Shale Corp.	2,240.50 (1)	T13, 14S, R8, 9W	8/6/73
S. R. Anderson	3,237.02 (3)	T11, 12S, R2, 3W (One lease partially in Utah County)	4/4/77
Brush Hellman Inc.	3,199.88 (2)	T12, 13S, R12, 13W	6/26/78
G. C. Harrison	2,823.80 (2)	T13, 14S, R7, 8W	9/2/75
P. V. Kendell	320.00 (1)	T14S, R8W	11/12/75

Table III-6 Con't

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION	DATE ISSUED
<u>JUAB Cont.</u>			
S. V. McCormick	1,160.00 (1)	T14S, R8W	4/7/75
Phillips Petroleum Co.	5,174.10 (4)	T11, 12, 13S, R15, 16W	3/5/79
R. E. Puckett	5,760.00 (5)	T13, 14S, R7-9W	12/3/73
Resource Leasing Corp.	638.76 (1)	T14S, R8W	8/6/73
Steam Corp. of America	1,767.88 (2)	T14S, R8W	8/6/73, 5/20/74
<u>MILLARD</u>	69,931.00 (74)		
Amax Exploration Inc.	3,374.21 (4)	T22, 23S, R6-8W	9/20/76, 4/18/77, 4/25/77
American Oil Shale Corp.	1,405.82 (3)	T22, 24S, R6, 7W	5/20/74
D. E. Armstrong	760.00 (1)	T15S, R7W	10/17/77
R. Barnes	640.00 (1)	T25S, R8W	12/23/74
R. C. Barr	160.00 (1)	T22S, R6W	4/25/77
C. F. Beckstrom	8,122.54 (8)	T19-21S, R5-9W	8/11/75, 12/21/77
J. E. Blankenship	1,158.89 (1)	T21S, R6W	10/25/77
J. G. Brown	4,306.18 (3)	T22, 23S, R5, 7W	5/31/77
J. K. Chatwin	1,468.32 (1)	T19S, R6W	1/27/76
Chevron Oil Co.	3,225.37 (3)	T24, 25S, R8, 9W	8/6/73
Davon Inc.	2,428.96 (2)	T19, 20, 23S, R7, 8W	12/17/73
D. F. X. Finn	4,452.36 (4)	T20, 21S, R8, 9W	3/5/74
G. C. Harrison	4,319.08 (2)	T19, 20S, R8W	12/15/75
A. N. Henderson	640.00 (1)	T23S, R8W	1/12/76
Intercontinental Energy	363.64 (1)	T24, 25, 26S, R7W (Partially in Beaver County)	5/27/75
E. A. Justice	480.00 (1)	T24S, R5W	6/23/75
M. F. Justice Jr.	640.00 (2)	T24, 25S, R5, 11W	1/21/74
J. K. Letts	1,374.88 (2)	T25, 26S, R7W (One lease Partially in Beaver County)	5/20/74
Magma Power	2,000.00 (1)	T17S, R9W	10/26/76
S. V. McCormick	8,203.65 (7)	T25, 26S, R9, 10W	8/6/73, 4/7/75, 8/1/75

Table III-6 Con't

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION	DATE ISSUED
<u>MILLARD</u> Cont.			
S. L. McGarry	2,881.53 (5)	T24, 25S, R6-8W	5/29/74, 7/19/76
Phillips Petroleum Co.	7,157.46 (7)	T15, 18, 19, 24, 25S, R6-8W	8/6/73, 9/22/75, 1/12/76, 2/9/76
R. E. Puckett	8,456.50 (7)	T15, 16, 23S, R5-9W	12/3/73
Resource Leasing Corp.	634.68 (1)	T14S, R8W	8/6/73
Steam Corp. of America	560.00 (1)	T25S, R3W	8/6/73
Thermal Power Co. of UT	717.24 (1)	T26S, R8W	8/6/73
<u>PIUTE</u>	2,520.00 (2)		
Moly Minerals Inc.	2,520.00 (2)	T28S, R1W	7/16/79, 7/2/79
<u>SANPETE</u>	2,358.00 (3)		
R. E. Puckett	2,358.01 (3)	T15, 16, 18S, R1-3E	12/3/73
SEVIER	4,455.00 (9)		
J. E. Blankenship	680.00 (1)	T26S, R3W	10/16/78
E. A. Justice	480.00 (1)	T26S, R5W	6/23/75
M. J. Justice Jr.	360.29 (1)	T25S, R5W	8/8/77
S. V. McCormick	2,735.80 (5)	T24, 25S, R3, 4W	10/21/74, 4/7/75, 4/21/75, 5/6/75
Steam Corp. of America	200.00 (1)	T25S, R3W	5/20/74
<u>UTAH</u>	21,683.00 (16)		
R. Barnes	2,281.29 (4)	T10, 11S, R1, 2W (One lease partially in Juab County)	1/20/75
R. E. Puckett	19,401.31 (12)	T5-7, 9-11S, R1, 2W	12/3/73
<u>WASATCH</u>	3,363.00 (4)		
R. E. Puckett	3,363.49 (4)	T3, 4S, R4, 5E	12/3/73

Table III-6 Con't

COUNTY & LESSEE	SIZE, ACRES & (NO. OF LEASES)	LOCATION	DATE ISSUED
<u>WASHINGTON</u>	5,514.00 (7)		
H. F. Justice Jr.	1,299.50 (3)	T37S, R15, 16W	2/23/76
G. W. Nevins	160.00 (1)	T40S, R16W	11/8/76
R. E. Puckett	800.00 (1)	T41S, R12W	12/3/73
M. W. Smith	3,253.81 (2)	T40S, R17W	10/26/76

Table III-6 Con't
New State Geothermal Leases
July - December 1979

COUNTY	SIZE, ACRES (No. of Leases)	LOCATION	DATE ISSUED
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BEAVER

Frederick E. Payne	1,280.00 (2)	T30S, R9W	8/9/79
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BOX ELDER

Diane Katz	400.00 (3)	T8H, R7, 8W	9/14/79
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PIUTE

Moly Minerals, Inc.	1,280.00 (2)	T28S, R1W	7/2/79
---------------------	--------------	-----------	--------

There are some general economic considerations cited by the Energy Sourcebook which assist in the successful development of geothermal energy. These include the following:

- (1) The extent and characteristics of the resources for most potential areas are not known with enough accuracy to predict the exploration and drilling required for development, both of which can add significantly to the total investment and discourage industry and financial institutions from committing capital for development.
- (2) Conversion efficiencies have not been proven for most systems suggested and these efficiencies will vary as the fluid temperatures vary from reservoir to reservoir.
- (3) Costs for all forms of energy production are rising, making it difficult to compare geothermal costs with other energy sources.
- (4) The geothermal industry does not have the same tax incentives as do other energy extraction industries.⁴

Resource Development Requirements

The resource development requirements for geothermal power plant projects which includes air, water and waste requirements are summarized in Appendix A. The energy resource requirements are summarized in Figure III-5. Clarence Bloomster in his Economic Analysis of Geothermal Energy Costs summarizes the resource development requirements as follows:

Geothermally driven generating units are limited in their economic size by the large size of the low pressure turbines they employ. [As shown in Figure III-5,] the costs of generating capacity, as affected by size and type of power unit, for exploration of a low salinity source, and illustrates two important points regarding costs. First, the unit economies of scale cease to increase at about 55 MW. Second, binary cycle units are the cheapest per unit of output. However, binary power cycle costs are particularly sensitive to the rate and efficiency at which heat is transferred from well-driven fluid to the material driving the turbine. Poor heat coefficients--rate of heat transfer per hour per unit area of heat exchanges per unit temperature difference between fluids (Btu/hr/ft²/ F) result in higher costs, as larger heat transfer areas (heat exchangers) must be

Figure III-5
THE EFFECT OF PLANT SIZE AND POWER CYCLE
OF GENERATING COSTS FOR ELECTRICITY

Source: Clarence Bloomster, Economic Analysis of Geothermal Energy Costs (Richland, Wash.: Battelle Pacific Northwest Laboratories, November 1975).

constructed. Heat exchanger costs vary directly with well fluid temperature, unit costs of exchangers, and heat transfer coefficients [As Figure III-5 shows]. Costs of units above 55 MW size are uniform. The dominant factors determining costs [and size] of power are the rate, and the cost of wells--that is, the heat delivered per hour related to the cost of installing the field plant to produce this heat. For a given temperature, there is a strong relationship between flow rates and energy costs. Once economies associated with larger units are exhausted, it makes more sense to replicate units. This replication improves system reliability, confirming the effects of the unavailability of a unit.

Geothermal units thus are small when compared with 800 MW coal fuel units or 1,200 nuclear units--the economic system for such energy sources.

Table III-7 presents a summary of future geothermal power plant developments in the Western United States. The Roosevelt plant is the only one planned for Utah. The future development of geothermal power plants in Utah is still at an exploratory stage.

The Energy Research Development Administration in 1975 outlined the following requirements for hydro-thermal technological development:

- (1) Reservoir engineering and field development to improve the economics and reduce the risk, for example, of premature reservoir failure. Tasks include improved technology for drilling, well digging, reservoir modeling, well simulation, and downhole pumps.
- (2) Development of technology to utilize geothermal energy including heat exchangers, condensers, total flow systems, and absorption refrigerator systems.
- (3) Work in brine chemistry, scale control, and corrosion and erosion restraint materials.
- (4) Construction of field facilities to test components.
- (5) Development of advanced systems and applications.
- (6) Study of environmental effects of field production and development to control emissions, efficiency, noise, and land subsidence.
- (7) Demonstration of pilot plants and commercial-scale units, with two such commercial-scale facilities tentatively planned.⁶

Table III-7

GEOTHERMAL ENERGY EXPLORATION

SURVEY METHODS

<u>Survey Method</u>	<u>Description</u>
Airborn Survey	Includes aerial photography, aeromagnetic surveys, and airborne infrared surveys, although the latter two methods are being used less.
Gravity Survey	This is a measurement of the gravitational attraction of the earth at any location. The results of gravity surveys yield, among other things, the depth and profile of the basement rock underlying a sedimentary basin and the location of faults.
Magnetic Survey	This is a measurement of the intensity of the earth's magnetic field at any location. This survey provides results similar to the gravity survey.
Passive Seismic Surveys	Such surveys record naturally occurring microearthquakes or seismic ground noise. Microearthquakes are recurring low intensity earthquakes, usually not felt by humans, caused by fracturing and displacement of subsurface rock along an active fault. Such active faults are often considered to be the flow conducts of geothermal water from depth. Seismic ground noise implies continuous low intensity vibrations in the subsurface and may be associated with geothermal areas.
Geologic and Hydrologic Surveys	Includes structural and stratigraphic mapping to detect recent faulting, to determine the distribution and age of young volcanic rocks, and the location and character of surface thermal manifestations. Hydrologic analysis includes temperature and discharge measurements of hot and cold springs, evaluation of surface and subsurface water movements, and collection of basic meteorologic data.

Table III-7 Cont.

<u>Survey Method</u>	<u>Description</u>
Geochemical Survey	Data obtained from chemical analysis of water and gas samples are used to determine whether the sample is vapor or hot water dominated, to eliminate temperatures and chemistry of the waters at depth, and to determine the source of recharge water. Analysis of the isotope content can be used to specify the origin of water in hydrothermal systems.
Heat Flow Survey	Vertical temperature gradients are measured in shallow boreholes (100 to 150 ft) drilled in an area considered prospective from other surveys.

Source: Energy Sourcebook, pp. 365-366

Table III-8

Future Geothermal Powerplants
(1977 - 78)

<u>Location</u>	<u>Capacity</u> (megawatts)	<u>Initial</u> <u>Operating Date</u>
<u>California:</u>		
The Geysers	500	1981
Salton Sea	10	1982
	10 (demonstration)	Unknown
	100	Unknown
	50	Unknown
Brawley	10	1979
Herber	200	Unknown
East Mesa	10	1979
	48 & 10	1980
<u>Nevada</u>		
Brady-Hazen	20 & 50	Unknown
	50	Unknown
<u>New Mexico</u>		
Baca No. 1	50 (demonstration)	1982
<u>Idaho</u>		
Raft River	10	1980
<u>Utah</u>		
Roosevelt	50	Unknown

Source: Geothermal Resource Council - Quoted in Annual Report 1977-78,
Western Interstate Energy Board/WINB pp. 18-19

Potential Environmental and Socio-Economic Impacts

Several analyses of potential environmental and socio-economic impacts have been performed. A summary of these analyses is presented here. If the reader desires further indepth analysis, he should consult the bibliography in Appendix E.

A small amount of impact data is available on geothermal energy which is compounded by the limited field environmental experience. However, the general conclusion of the environmental and socio-economic impact of a geothermal power plant is that the overall impact will be less than the impacts of nuclear or fossil fuel power plant developments.⁷ In general, the environmental impacts are relatively site dependent, that is the drilling takes place in the immediate vicinity of the power plant or other facility. Transportation is limited to pipelines and power lines; pipelines could extend no more than a few miles and powerlines could be limited by the relatively small capacity of most geothermal plants. However, most of the negative impacts would occur during the drilling and construction phases of the power plant development.⁸

(1) Air Pollution Impacts

Noncondensable gases such as hydrogen sulfide, carbon dioxide, methane, and nitrogen found in the vapor phase of a geothermal source, could cause serious air pollution if released.

Hydrogen sulfide ranks as the most likely potential environmental hazard, occurring at 16 times the toxic level in undiluted geothermal stream at the Geysers, although normally the gas is dispersed in the atmosphere before it reaches a toxic level.

Mercury is also a potential hazard in some geothermal fluids and in some geothermal fluids it would have to be monitored continuously.

(2) Water Pollution

Ground water contamination can result from interference with aquiferous fresh water during the drilling and production phases.

Introduction of highly saline or toxic geothermal fluids to surface waters, resulting from brine disposal, blow-outs, or spills could cause water and thermal pollution, although reinjection of spent fluids into the reservoir greatly mitigates the environmental risk.

(3) Land Subsidence

Sinking of the earth's crust sometimes occurs when supporting fluids are removed from underground reservoirs. Prevention of subsidence involves replacement fluids, usually the spent geothermal fluids.

(4) Seismic Activity

It is possible for changes in reservoir pressures to cause an increase in seismic activity. Although not well studied to date, either injection or withdrawal of large volumes of fluid have a powerful effect on the stress in a fault zone to cause a major earthquake. On the other hand, minor changes in seismic activity may relieve accumulated strain before a major earthquake occurs.

(5) Noise Pollution

Noise Pollution can result during venting of geothermal steam through relief valves. Mufflers are now being developed.

Drilling and construction activities can also produce noise pollution.

(6) Land Modification

Most geothermal power plants would be developed in areas not now industrialized or urbanized, thus necessitating disruption of existing land use and possibly disturbing wildlife. However, it is also true that since such facilities would be smaller than most power plants, fossil or nuclear, and since electricity or steam would usually not be transmitted great distances, the negative impacts on land use and wildlife would be minimal and generally restricted to the immediate area of the plant. Also, a developed geothermal field need not be incompatible with other land uses. For example, in Italy farms, orchards and vineyards are interspersed among the pipelines and wells. At the Geysers, cattle graze and wildlife live in areas immediately adjacent to the power plant. Geothermal developments would not be drilled normally in recreational areas, especially in federal and state parks.

(7) Legal and Institutional Problems

Resource definition. This definition varies from state to state. For example, in Hawaii, geothermal resources are defined as minerals while in Wyoming the resource is defined as a water resource.

Ownership Rights. Federal grants of public land retain mineral rights for the Federal Government, while some state grants include mineral rights.

Control over use of water. Some states such as Oregon, California and Colorado have laws which prohibit transporting water out of the state.

Overlapping and conflicting regulations. Conflicting jurisdictions for permits, licenses, taxes, environmental control, etc., exist between federal, state and local governments.

Leasing Complications. Most leasing contracts must be negotiated through the Department of Interior's land classification and leasing policies, maintaining that in many cases, they cause unwarranted delays in resource development.

Environmental Problems. The lack of environmental impact data tends to discourage or delay the acceptance of geothermal technologies.

(8) Competitive Economics.

Exists continued and increased government support in R & D and federal loan guarantee programs.

Willingness of industry to make financial investments.

Successful compliance with EPA without prohibitive expenditures or environmental control technologies.

Continued high costs for more conventional energy sources.

Integrated operation of geothermal power stations from exploration to production rather than the purchase of steam or hot water by the utility companies from independent suppliers (the effect would be increased investment cost per kw of capacity but decreased production cost per k wh of energy.)

Improved technology for drilling and conversion methods.

Expedition of leasing and regulatory procedures.⁹

Transportation Tradeoffs

The method of transportation or transmission of electricity generated from geothermal power plants will primarily be a function of the location of the market for the electricity. Figure III-6 shows the principal electric transmission lines and main distribution feeders in Utah. At the present time, the most plausible alternative for transmission of electricity generated from geothermal resources is to local Utah market areas.

Figure III-6
PRINCIPAL ELECTRIC TRANSMISSION LINES AND
MAIN DISTRIBUTION FEEDERS

Source: Utah Power & Light Company (Salt Lake City, Utah, 1977).

Section III - Footnotes

¹William H. Eaton, Geothermal Energy (U.S. Energy Research and Development Administration, office of Public Affairs: 1975), p.ii.

²Energy Sourcebook,
p. 365

³Ibid. p. 359

⁴Ibid. p. 368

⁵Sheldon L. Bierman, David F. Stover, Paul A. Nelson and William J. Lamont, Geothermal Energy in the Western United States: Innovation Versus Monopoly (Praeger Publishers, New York: 1978), pp. 1920.

⁶Ibid. p. 52

⁷Op. Cite., Energy Sourcebook, p. 366.

⁸Ibid. p. 367

⁹Ibid. pp. 367 and 368

SECTION IV

COAL RESOURCES IN UTAH

The coal resources in Utah represent a significant share of the total U.S.'s low sulfur, high quality coal reserve. However, Utah has only a small share of the total U.S. coal reserve. Utah's total reserve is approximately 23.3 billion tons or 1.3 percent of the total U.S. reserve. Utah ranks fourteenth in its share of the U.S. coal reserves.

Resource Potential and Location

As of 1979, there are approximately 23.3 billion tons of recoverable coal reserves in Utah. One-third of these reserves are located in the Kaiparowits Plateau and approximately one-fourth of Utah's coal reserves are found in the Wasatch Plateau. (See Table IV-1.) Figure IV-1 shows Utah's coal reserves by type of coal in relationship to the United State's total coal reserves, while Figures IV-2 and IV-3 present a detailed summary of Utah's coal regions.

As shown in Table IV-2, almost one-third of Utah's coal reserves are found in Kane County, 21 percent in Carbon County, 18 percent in Emery County and 15 percent in Garfield County. (Note: The total tonage is not the same as shown in Table IV-1, but it is felt that the distribution of the coal reserves by county would be approximately the same.) An analysis of Utah's coal in terms of sulfur, BTU per pound, moisture volatile matter, fixed carbon and ash is presented in Table IV-3.

Finally, Table IV-4 presents by county the annual coal production in 1979. Carbon and Emery Counties currently exhibit the largest share of coal production in the state.

Table IV-1

Identified Remaining Recoverable Coal
Resources In Utah* Selected
Coal Fields

(1979)

<u>Coal Field</u>	<u>Remaining Reserves (Million of Tons)</u>	<u>Percent of Utah Total</u>
Kaiparowits Plateau	7,878	33.7%
Wasatch Plateau	6,047	25.9
Book Cliffs	3,071	13.1
Kolob	2,012	8.6
Alton	1,509	6.5
Emery	1,425	6.1
Other Field	1,447	6.2
Utah Total	23,389	100.0%

* Includes measured, indicated and inferred reserves.

Source: Utah Geological and Mineral Survey, 1979.

FIGURE IV -I

DISTRIBUTION OF COAL IN THE
U.S. COAL PROVINCES

Source: Wade V. Campbell and Rodney D. Millar, An Assessment of the Energy Resources in Utah: Part II Coal in Utah (office of the State Science Advisor, Salt Lake City, Utah: 1978), p.9.

Figure IV-2
UTAH COAL FIELDS

Compiled by Bureau of Economic and Business Research, University of Utah, in cooperation with Utah Geological and Mineral Survey (Salt Lake City), 1978.

Appendix Figure V-3. Coal Fields of Utah

Figure IV-3
COAL REGIONS IN UTAH

Table IV-2

Original Principal Resource By County
(Millions of Tons)

County ^a (by position)		Resource	Percent
1.	Kane	7,016.9	28.9
2.	Carbon	5,096.3	20.9
3.	Emery	4,388.8	18.0
4.	Garfield	3,698.5	15.2
5.	Sevier	2,070.8	8.5
6.	Iron	650.8	2.7
7.	Sanpete	489.5	2.0
8.	Grand	293.6	1.2
9.	Summit	186.0	0.8
10.	Wasatch	177.3	0.7
11.	Uintah	177.1	0.7
12.	Duchesne	53.9	0.2
13.	Washington	25.3	0.1
14.	Wayne	23.6	0.1
15.	Morgan	1.1	---
TOTAL		24,349.5	100.0

a: Counties not listed have no resource.

Note: Table 2 gives a principal resource figure of 24,349 million tons, nearly one billion tons greater than cited above by Averitt (2). The estimates in Table 2 have not excluded tonnage removed from the resource category due to production activities. Table 1 reflects this change in resources and is therefore a lower estimate.

Source: H. H. Doelling, Central Utah Coal Fields, Utah Geological and Mineral Survey, Monograph Series No. 3, 1972.

Table IV-3

AVERAGE PROXIMATE ANALYSES OF UTAH COAL*
(Percent by Weight)

Field and Area	No.**	Percent Sulfur	No.	BTU/lb	No.	Percent Moisture
Kaiparowits Plateau	129	0.87	161	11,999	137	11.3
Smoky Mountain Area	91	0.75	91	12,401	77	9.6
Escalante area	24	1.26(0.98)	53	11,563	40	10.5
Tropic area	14	0.98	17	11,207	20	19.5
Wasatch Plateau	722	0.64	788	13,407	914	6.1
North five quads	159	0.69	184	13,147	210	7.2
Hiawatha quads	538	0.62	582	13,470	608	5.4
South eight quads	25	0.61	22	12,747	25	8.8
Book Cliffs	1,149	0.61(0.89)	1,242	13,405	1298	4.6(4.8)
Castlegate area	784	0.55	854	13,402	875	4.3
Soldier Canyon area	206	0.51	225	13,158	233	4.8
Sunnyside area	67	1.15	58	13,331	79	5.0
Woodside area	92	0.74	105	13,399	111	5.5
Kolob	76	5.95(4.44)	73	11,664	95	8.6(10.2)
Cedar City area	67	6.27	64	11,426	86	8.2
Orderville area	9	2.51	9	11,771	9	12.1
Alton	28	1.16	27	10,770	28	17.8
Alton area	13	1.33	12	12,070	13	17.0
Skutumpah area	11	1.07	11	10,166	11	19.3
Cannonville area	4	0.87	4	8,530	4	15.8
Emery	46	1.07	44	12,338	47	7.4
Sego	27	0.66	18	12,012	27	9.1
Mt. Pleasant	7	0.83	7	13,341	7	3.4
Tabby Mountain	7	1.05	7	10,987	7	15.9
Frontier zone	3	0.87	3	10,065	3	19.4
Mesaverde zone	4	1.18	4	11,627	4	15.0
Henry Mountains	16	1.37	16	12,483	16	8.0
Emery zone	13	0.96	13	12,480	13	9.8
Ferron and Dakota zones	3	3.10	3	13,185	3	5.3
Coalville	41	1.50	45	12,187	53	12.0
Vernal	36	1.60	36	11,367	36	9.3
Mesaverde zone	2	0.80	2	8,950	2	12.8
Frontier zone	34	1.60	34	11,509	34	9.1
Salina Canvon	12	0.49	11	12,299	13	7.6
Wales	8	4.53	6	10,655	12	5.0
Sterling	1	0.98	1	12,874	1	8.2
Harmony	11	3.54	11	9,780	11	6.7
Lost Creek	2	0.65	2	10,197	2	17.9
Henrys Fork						
Manning Canvon Shale	2	3.02	2	11,320	2	5.4
San Juan	2	3.00	2	11,282	2	3.5

Table IV-3 Con't

Field and Area	No.	Percent Volatile Matter	No.	Percent Fixed Carbon	No.	Percent Ash
Kaiparowits Plateau	164	43.6	164	47.3	165	9.0
Smoky Mountain Area	91	42.5	91	48.8	91	8.7
Escalante area	53	45.4	53	46.8	54	7.8
Tropic area	20	44.4	20	41.8	20	13.8
Wasatch Plateau	773	44.7	773	48.3	812	6.9
North five quads	188	44.6	188	48.8	204	6.6
Hiawatha quads	563	44.8	563	48.1	583	7.1
South eight quads	22	41.5	22	51.2	25	7.3
Book Cliffs	1,198	43.3(41.3)	1,197	49.8(51.6)	1,238	7.0
Castlegate area	820	44.5	819	48.6	845	6.9
Soldier Canyon area	218	40.6	218	51.9	225	7.5
Sunnyside area	63	40.2	63	53.1	68	6.7
Woodside area	97	39.8	97	53.1	100	7.1
Koloni.	95	44.3	95	46.4(43.7)	96	12.1
Cedar City area	86	42.9	86	45.5	87	11.6
Orderville area	9	45.7	9	41.2	9	13.1
Alton	27	41.2	27	47.6	28	11.2
Alton area	12	40.2	12	50.4	13	9.4
Skutumpah area	11	43.6	11	46.6	11	9.8
Cannonville area	4	37.9	4	41.6	4	20.5
Emery	46	41.0	46	49.4	47	9.6
Sego	23	37.4	23	50.6	27	12.0
Mt. Pleasant	7	44.4	7	47.3	7	8.4
Tabby Mountain	7	43.7	7	46.9	7	9.7
Frontier zone	3	41.6	3	45.8	3	12.6
Mesaverde zone	4	44.9	4	47.4	4	7.8
Henry Mountains	16	41.2	16	47.1	16	10.5
Emery zone	13	40.6	13	48.9	13	10.5
Ferron and Dakota zones	3	46.1	3	42.6	3	11.3
Coalville	52	43.8	53	51.1	54	5.1
Vernal	36	39.6	36	48.0	36	12.8
Mesaverde zone	2	42.7	2	39.8	2	17.5
Frontier zone	34	39.3	34	48.3	34	12.4
Salina Canyon	11	44.8	11	44.7	13	10.5
Wales	13	36.0	13	48.5	13	15.5
Sterling	1	46.4	1	47.0	1	6.6
Harmony	11	11.2	11	60.2	11	28.6
Lost Creek	2	33.6	2	43.9	2	22.5
Henrys Fork						
Manning Canyon Shale	2	37.3	2	49.6	2	13.1
San Juan	2	29.2	2	49.0	2	21.8

Note: * All figures have been converted to a dry weight basis except present moisture.

** Number of analyses made.

- The numbers in parenthesis are estimates of the true average where bias is present because of too many samples from one particular mine or area.
- Caution is urged when interpreting these data as representative of an entire area or coal field because the analyses made do not necessarily represent an entire coal seam or field. This is especially important when the number of analyses are small or are taken from outcrops.

Data Source: H. H. Doelling, Central Utah Coal Fields, Utah Geological and Mineral Survey, Monograph Series No. 3, 1972.

Table IV-4

Coal Production and Properties in Utah

(1979)

<u>Carbon County</u>		
<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Braztah Corp.	Braztah, Spring Canyon, Castle Gate and Kenilworth Area	500,000 Or More
California Portland Cement Co.	Soldier Canyon Mine, Book Cliffs Region	50,000-500,000
Duvels Inc.	Duvels Properties, Soldier Canyon Area	No Production
Energy Fuels Corp.	McKinnon, West of Clear Creek	No Production
E. R. Evarz	Evatz Properties, Soldier Canyon Area	No Production
Franklin Real Estate Co.	Castle Gate Area, North of Helper	No Production
ITEL Resources	Colombine, Scofield Area	No Production
Kaiser Steel Corp.	Sunnyside Mine	500,000 Or More
Kaiser Steel Corp.	Sunnyside Mine, Sunnyside Area	50,000-500,000
Kaiser Steel Corp.	Sunnyside Mine, Sunnyside Area	50,000-500,000
Kanawha Hocking Coal & Coke Co.	Kanawha Properties, South of Clear Creek	Data Withheld
Kennecott Coal Co.	Kennecott, Knight Ideal Mine, Wellington Area, Soldier Canyon Vicinity	No Production
John Peperakis	Peperakis Properties Kenilworth Area	No Production
Plateau Mining Co.	Star Point Mines, Wattis Canyon	500,000 Or More
Routt County Development	McKinnon, Southwest of Scofield	No Production
W. R. Skaggs	Skaggs Coal, Consumers Area	No Production
Swisher Coal Co.	Gordon Creek, Swittes Area	50,000-500,000
U.S. Fuel Co.	King Mine, Mohrland, North Hiawatha, Southern Fork, Hiawatha Townsite	500,000 Or More

Table IV-4 Con't
Coal Production and Properties in Utah
(1979)

<u>Carbon County Cont.</u>		
<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
U.S. Steel Corp.	Columbia Coal Mine, East Carbon City	500,000 Or More
U.S. Steel Corp.	Geneva Mine, Horse Canyon, Sunnyside, Tidewell and Rideout District, Wellington Plantsite	500,000 Or More
Valley Camp Coal Co.	Utah, North of Clear Creek, Belina, Whiskey Canyon Area	50,000-500,000
Wasatch Coal Co.	Wasatch Coal Properties, West of Helper	No Production
Western Reserve Coal Co.	Standard-Columbine Properties, Scofield Area	No Production
Zion's Securities Corp.	Zion's Securities Group, Book Cliffs Region	No Production
<u>Emery County</u>		
American Coal Co.	Beehive and Deseret Mines, West of Huntington	500,000 Or More
Lloyd L. Barton	Barton Properties, Southwest of Castle Dale	No Production
D. Bastain, T. L. Hanks	Coal Properties, Huntington Area	No Production
Consolidation Coal Co.	Emery Surface Mine, South of Emery, Christiansen Wash Area	50,000-500,000
Consolidation Coal Co.	Emery Properties	No Production
Co-op Mining Co.	Co-op Mine, Northwest of Huntington	50,000-500,000
John R. Dellenback	Bellenback, Huntington Area	No Production
Herbert Fleishhacker,	Fleishhacker Properties, Huntington	No Production
A. V. Gustafson	Gustafson Properties, West of Castle Dale	No Production
Bill Halls	Halls Properties, West of Castle Dale	No Production

Table IV-4 Con't
Coal Production and Properties in Utah
(1979)

Emery County Cont.

<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Helco Coal Co.	Black Majic Mine, Northwest of Huntington	No Production
Hunter Investment Co.	Hunter Properties, Cooper Boy, Coal Cliffs Area, East of Emery	No Production
Ivie Creek Coal Co.	Ivie Properties, Dog Valley Region, South of Emery	No Production
O. Eugene Johansen	Johansen, West of Orangeville	No Production
Sam Lee	Lee Coal Properties, West of Clawson	No Production
Malcolm N. McKinnon Estate	McKinnon Estate Properties, West of Huntington	No Production
Utah Power & Light Co.	Deer Creek Mine, Peabody Properties, Wilberg Mine, West of Huntington	500,000 Or More
Phelps Dodge Corp.	Phelps Dodge Properties, Southwest of Clear Creek	No Production
Earl J. Robertson	West of Orangeville	No Production
Sun Valley Coal Co.	Dickert & Eddy Properties, Sun Valley Area	No Production
Swisher Coal Co.	Huntington Canyon Properties, Southwest of Clear Creek, Huntington Canyon, Southwest of Hiawatha	No Production
Trail Mountain Coal Co.	Trail Mountain Properties, Huntington Area	No Production
U.S. Fuel Co.	King Mine, Hiawatha, Hiawatha-Mohrland	500,000 Or More
U.S. Fuel Co.	UV Industries, Seeley Mountain Vicinity	No Production
U.S. Steel Corp.	Horse Canyon Area, South of Sunnyside	No Production
Western States Coal	Western States Properties, Dog Valley Mine, South of Emery	Data Withheld
Ira W. Wickliffe	Wickliffe Coal, Northwest of Huntington	No Production

Table IV-4 Con't
Coal Production and Properties in Utah
(1979)

<u>Garfield County</u>		
<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Amaz Inc.	Henry Mountains Coal Properties, Wildcat Mesa Area	No Production
Discovery 21, Enterprises Inc.	Shakespeare Mine	No Production
Garfield Coal Co.	Davies, East of Tropic	No Production
Horst Schober Heirs	Schober Heirs, Dugout Creek Vicinity, Henry Mountains	No Production
<u>Grand County</u>		
Harlan Management Corp.	Black Ace Mine, Sego Area	Data Withheld
Michael Shumway & James Keogh	Shumway-Keogh Mine, Book Cliffs Area, Northwest of Harley Dome	No Production
Wes-Pac Energy Corp.	Thompson Canyon Mine, Thompson Area	1-50,000
<u>Iron County</u>		
Bekins Mineral Resources Inc.	Old Kirker Mine, Gold Springs Area Gold Springs Mining District	No Production
Charles E. Bryan	Bryan Properties, East of Cedar City	No Production
Douglas Clark	Clark Properties, Gold Springs Mining District	No Production
Joseph G. Dooley	Dooley Properties, Northeast of Kanarraville, Cedar Mountains	No Production
A. L. Graff	Graff Properties, Cedar Mountains South of Cedar City	No Production
Jones Bros.	Koal Creek Properties, Koal Creek Area, Southeast of Cedar City	No Production
Koal Creek Coal Co.	Jones-Bulloch Mine, East of Kanarraville	No Production
Everett M. Koontz	Koontz Properties, Koal Creek Area, Southeast of Cedar City	No Production

Table IV-4 Con't
Coal Production and Properties in Utah
(1979)

<u>Iron County Cont.</u>		
<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Henry H. Lunt	Lunt Coal Properties, Koal Creek Area, Southeast of Cedar City	No Production
I. C. Salter	Salter Properties, Kolob Terrace Area, Cedar Mountains	No Production
V. L. Spradling	Sprading, Morris, Cronk et al Properties, Webster Area, Southeast of Cedar City	No Production
Joy B. Tiernan	Tiernan Coal Co., West of Cedar City	No Production
Naomi P. Urie	Urie Coal, Webster Area, Southeast of Cedar City	No Production
Webster Coal Co.	Webster Coal Mine, Koal Creek Area	No Production
Rulon S. Wood	Wood & Leigh Coal	No Production
Zion's Co-operative, Mercantile Institution	Zion's Co-op Group	No Production
Zion's Securities Corp.	Securites Group	No Production
<u>Zane County</u>		
Energy Reserves Group Inc.	Skutumpah Canyon Coal Mine, Richfield Area	No Production
5 M Corp.	John Henry Mine, Southwest Smoky Mountain Area	No Production
King Cannel Coal Co.	King Cannel, Glendale Area	No Production
Nevada Electric Investment Co.	Alton Coal Mine, Alton Townsite	No Production
Resources Co., Mono Power Co., & New Albion Resources	Resources Properties, Johnson Vicinity	No Production

**Coal Production and Properties in Utah
(1979)**

San Pete County

<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Ferron Canyon Coal & Gas Co.	Ferron Canyon, South Sanpete School District, Wasatch Plateau, Northwest of Ferron	No Production
William M. Thomas	Thomas Coal, South Sanpete School District, Wasatch Plateau, Northwest of Ferron	No Production

Sevier County

Don H. Brown	Brown Properties, Salina Canyon Vicinity	No Production
Cordillera Petroleum of Canada Ltd.	Cordillera Properties, Southeast of Sevier Valley, Canyon Highway	No Production
Coal Search Corp.	Knight Mine, Rock Canyon Mine, Southwest of Emery	1-50,000
Southern Utah Fuel Co.	Southern Utah Fuel Mine, Convulsion Canyon, East of Salina	500,000 Or More

Summit County

Chappell Coal Co.	Chappell Mine, Coalville	No Production
A. C. Nielsen	Nielsen Properties, Upton Area	No Production
M. E. Taylor	Taylor Properties, Coalville District, Coalville	No Production
Rocky Mountain Energy Corp.	Union Coal Properties, Southeast of Echo, Upton Area	No Production
Utah Coal & Energy Inc.	Blackhawk, Upton Area, East of Coalville	1-50,000
Weber Coal Co.	Weber Coal, North Summit District Coalville	No Production
Zion's Securities Corp.	Zion's Securities Group, North Summit District, Southeast of Echo, Upton Area	No Production

Table IV-4 Con't

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Coal Production and Properties in Utah
(1979)

<u>Uintah County</u>		
<u>Producer</u>	<u>Location of Properties</u>	<u>Annual Production (In Tons)</u>
Energy Plus Inc.	Mill Draw, Brush Creek Area, East of Stanaker Reservoir	No Production
Lawrence Wardle	Wardle Properties, Northwest of Maeser	No Production
<u>Wasatch County</u>		
H. Clay Cummings	Cummings Properties, East of Woodland	No Production
<u>Wayne County</u>		
Atlas Resources Inc.	Factory Butte Properties, Northwest of Hanksville	No Production

Source: Carlton H. Stone, Utah Mineral Industry and Operator Directory 1979 (Salt Lake City, Utah: Utah Geological and Mineral Survey, June 1979).

Resource Technology, Development and Production Status

According to a recent report by the Office of the State Science Advisor entitled, Utah Energy Resources: Part II Coal In Utah, "Utah's coals are among the most attractive of any in the country for use in direct combustion since they generally exhibit sulfur contents lower than one percent by weight with a high proportion as low as 0.5 to 0.7."¹ There are three primary coal conversion technologies which include: coal gasification, coal liquefaction, and coal bed gas collection and in situ technologies.

Coal Gasification. Coal gasification is the process of converting coal to low, medium, and high BTU gas. (See Table IV-5 for a more detailed description of these gases.) This conversion process required a chemical and physical transformation of solid coal. A list of the conversion processes are shown in Table IV-6. Each conversion process exhibits unique characteristics, however, each process does generally follow the same steps to convert coal to gas. These steps include: (1) coal preparation and pretreatment, (2) gasification, (3) shift conversion, (4) methanation. (See Figure IV-4.)

Coal Liquefaction. Coal liquefaction is the process of producing a low-sulfur fuel oil or the production of a synthetic crude oil which could be processed further in a refinery for the production of gasoline and other distillate fuels from coal.² (See Figure IV-5.) Currently, there are three methods for converting coal into liquid hydrocarbon fuels. These methods include: synthesis gas, pyrolysis and hydrogenation. Tables IV-7 through Table IV-10 present a summary of these coal liquefaction processes.

Table IV-5

Description Coal Gasification Gases

<u>Type</u>	<u>Heating Value (BTU per SCF)</u>	<u>Gas Use</u>
Low-BTU	100-250	One of the cheapest of the gaseous fuels produced from coal and can be used economically only on site, either as a fuel feedstock or for electrical power generation in combined gas-steam turbine. On an equivalent-BTU basis, conversion of coal to low-BTU gas is less complex than conversion to high-BTU gas, and the capital costs are lower.
Medium-BTU	250-500	Gas is usually a feed gas for producing high-BTU gas.
High-BTU	950-1,000	This gas can be substituted for natural gas and can be distributed economically to consumers in the same pipelines now used to carry natural gas. Natural gas, a widely used heating fuel and industrial feedstock, is composed essentially of methane and contains virtually no sulfur, carbon monoxide, or free hydrogen.

Source: Alexander McRae, Janice L. Dudas, and Howard Rowland, ed., The Energy Sourcebook (Aspen Systems Corporation, Maryland: 1977), p.311.

Table IV-6

GASIFICATION PROCESSES AND STATUS

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
High-Btu Processes						
ATGAS-PATGAS	Applied Technology Corp., Pittsburgh, Pa.	Coal, crushed and dried, is injected into a molten iron bath through steam lances. Oxygen is introduced through lances located at the iron bath surface. Coal dissolves in the molten iron where the volatiles crack and are converted into carbon monoxide and hydrogen. Sulfur in the coal migrates to a fine slag floating on the molten iron, and forms calcium sulfide. The slag, containing ash and sulfur, is continuously withdrawn from the gasifier and desulfurized with steam to yield sulfur and desulfurized slag. The raw gas from the gasifier can be used as medium-Btu fuel or upgraded to high-Btu fuel.	All U.S. coals			The process has been under investigation in laboratories since 1967, and has been demonstrated in short-duration runs in a 2-foot internal diameter gasifier. Plans for further development involve a larger gasifier to demonstrate long-duration operation.
BI-GAS	Bituminous Coal Research, Inc., Pittsburgh, Pa.	Coal is introduced into the upper section of a two-stage reactor where it is contacted with hydrogen-rich gas and partially gasified. The hydrogen-rich gas is produced in the lower section of the reactor by the slugging gasification of recycle char with oxygen and steam. The product gas must be methanated to produce high-Btu gas.	All U.S. coals	120	2-3	Construction of the pilot plant was completed in mid-1976, and shakedown and operation started.
Chevron	Chevron Research Co.	High-Btu gas is produced from a wide range of organic feeds such as lignite and organic waste materials. The organic feed is reacted with steam at 300-800 psi and 1,700°-1,400° F in the presence of an alkali metal catalyst (e.g., K ₂ CO ₃). High Btu gas is produced by the catalytic steam reforming of the products of degradation of the feed.				Details of the development of the process are not available.

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
CO ₂ Acceptor	Consolidation Coal Co., Pittsburgh, Pa.	Coal is charged to a devolatilizer and is contacted at 300 psi with hydrogen-rich gas from a gasifier vessel. Calcined dolomite (the acceptor) is added to both vessels, where it reacts with carbon dioxide. Acceptor regeneration and ash removal is done in an air blown regeneration vessel where spent char is combusted. The product gas must be purified and methanated to produce high-Btu gas.	Lignite Subbituminous	40 (pilot plant)	2	The objective of CO ₂ acceptor process development is to keep the pilot plant operating to identify and resolve process and equipment problems relevant to commercialization. Process efficiency of 77 percent has been demonstrated. The pilot plant is being operated on an integrated basis with the liquid phase methanation process.
Electrolytic Gasification	Iowa State Univ. Ames, Iowa	A fluidized bed of conducting particles is heated by passing an electrical current through the bed. The bed itself acts as a resistor between electrodes placed in contact with the bed. Reacting steam and coal char in the reactor provide a wide range of hydrogen-carbon monoxide mixtures, as well as mixtures containing methane suitable for upgrading to high-Btu gas.				Four- and 12-inch-diameter reactors have been successfully operated. The process is being integrated with pilot plant tests of the HYGAS process electro-gasifier.
Exxon	Esso Research and Engineering Co., Baytown, Texas	Coal is reacted with steam in a fluidized-bed gasifier at 1,500° F-1,700° F. A stream of circulating char is withdrawn from the gasifier and partially burned with air in a char heater. The heated char is returned to the gasifier after separation from the flue gas. The medium-Btu gas produced can be upgraded to high Btu gas.	All U.S. coals			A 0.5 ton/day pilot plant has been in operation for several years.
Garrett's Coal Gasification	Garret Research & Development Co., La Verne, Calif.	Coal is introduced into a simple reactor at atmospheric pressure where gas is produced by rapid devolatilization of coal. Large amounts of excess char are produced.	All U.S. coals			Garrett, in conjunction with Colorado Interstate Gas, initiated development of the coal-gasification process in 1971. The process has been successfully evaluated in a pilot plant. The results of the pilot plant testing provided data that were evaluated by Combustion Engineering subsidiary, Lunken Co., to provide a detailed design for a 40,000 ton/day commercial plant. The plant would yield

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
Garrett's Coal Gasification (Cont'd.)						<p>250 million scf/day of pipeline quality gas and sufficient char to feed a 1,200 MW power plant.</p> <p>Garrett plans a 250 ton/day demonstration plant to be located near a power utility. Design and construction of the commercial plant could be started during operation of the demonstration plant.</p> <p>Operation of the commercial-scale pyrolysis reactor has been simulated with the operation of a continuous 3-16 lb/hour laboratory-scale reactor, which had the same configuration as the projected commercial unit except that its heat source was electrical. Results have indicated yields of pipeline-gas equivalents ranging from 4,500 scf/ton of MAF coal at 1,500° F to 7,500 scf/ton at 1,700° F, depending on coal type. Commercial-scale operation should yield an additional 1,000 scf/ton at 1,700° F of pipeline-gas equivalent by recycling the tar produced in the pyrolysis step to the reactor for further cracking.</p> <p>The commercial plant could be on-stream in 1980.</p>
Hydrane	U.S. Bureau of Mines, Pittsburgh Energy Research Center, Pittsburgh Pa.	Crushed raw coal is fed to a two-zone hydrogenation reactor operated at 1,000 psi and 1,650° F. In the top zone, the coal falls freely through a hydrogen-rich gas containing some methane from the lower zone. About 20% of the carbon is converted to methane. The char from the top stage falls into the lower zone where hydrogen feed gas maintains the particles in a fluidized state and reacts with about 34% more of the carbon to make methane. Char from the lower zone is reacted with steam and oxygen to generate the needed hydrogen.				<p>A second-generation hydrane process is in the engineering evaluation and design phase of development. This phase is scheduled to continue through the third quarter of FY 1978. Construction of a process development unit is scheduled to begin early in FY 1977 and continue through FY 1979, at which time the operation phase will begin.</p> <p>Laboratory studies are being conducted to acquire yield data, test operability using various coals, and obtain hydrogasification kinetic scale-up data.</p>

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
HYGAS	Institute of Gas Technology, Chicago, Ill.	Ground, dried coal is pretreated with air, slurried with by product oil, and fed to a two-stage fluidized bed hydrogasifier operating at 1,000-1,500 psia. Hydrogen-rich gas for the reaction can be furnished by processes using electric energy or oxygen, or by the steam-iron process. Gas from the reactor must be purified and methanated to produce high-Btu gas.	All U.S. coals	75 (pilot plant)	1.5	The pilot plant is being operated to obtain data. Improvements in oil/gas separation and oil recovery are being developed. An ash-agglomerating gasifier that could improve overall char utilization of the process is in operation. A decision to connect the steam-iron unit for hydrogen production from char will be made in FY 1977.
Koppers-Totzek	Heinrich Koppers GmbH Essen, W. Germany	Raw coal is dried, ground, and charged to a gasifier by a screw conveyor with a mixing head in which oxygen and steam are added. The reactor operates at atmospheric pressure and at 2,700° F. The product gas, mostly hydrogen and carbon monoxide, can be methanated to produce high-Btu gas.	All U.S. coals			<p>There are 16 Koppers-Totzek plants around the world, none of which is in the United States; five new plants are being built.</p> <p>An interesting new development of Heinrich Koppers and Imperial Chemical Industries (I.C.I.), Billingham, U.K., is a combined carbon monoxide-shift conversion and methanation unit. This unit's reactor uses a nickel catalyst that simultaneously promotes both shift and methanation reactions. Testing of this reactor by I.C.I. on a pilot scale has indicated that commercially acceptable lifetimes for the catalysts can be expected.</p> <p>A demonstration plant will be built in Germany to produce 2.6 scf/day from a coal feed of 145 tons/day. The Koppers-I.C.I. combined shift conversion and methanation reactor will be installed in the demonstration plant to upgrade the Koppers-Totzek gasifier raw gas to pipeline gas.</p> <p>Estimates for a Koppers-Totzek plant producing 250 million scf/day of high-Btu gas indicate a coal feed rate of 25,000 short tons/day to a battery of 24 Koppers-Totzek gasifiers.</p>

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
Koppers-Totzek (Cont'd.)						In the United States, Northern Illinois Gas Co. and the State of Illinois are studying the process, among others, for application at their proposed 80-90 million scf per day synthetic natural gas demonstration plant to be completed in Illinois in the early 1980s.
Lurgi Pressure Gasification	Lurgi Gesellschaft für Wärme- und Chemotechnik mbH Frankfurt, West Germany	Crushed coal is fed to the gasifier vessel through lock hoppers, and travels downward as a moving bed. The process operates at 350 to 450 psi. Steam and oxygen are introduced through a revolving steam-cooled grate, which also removes ash at the bottom of the gasifier. The hydrogen-rich gas passes up through the coal bed, producing some methane by hydrogenation of coal. The product gas is purified and methanated to produce high-Btu gas.	Noncaking coals			The first commercial plant was constructed in 1936 and, to date, 14 plants (comprising 58 units) have been built and additional plants, either with or without a methanation step, are under construction or in the planning stages.
Molten Salt	M. W. Kellogg Co. Piscataway, N.J.	Crushed and dried coal, oxygen, and steam are injected into a high-purity alumina reaction vessel with molten sodium carbonate. Coal-steam reaction is catalyzed by the molten salt contained in the reactor. The product gas can be purified and methanated to produce high-Btu gas.	All U.S. coals			<p>In early tests of the process, under Office of Coal Research sponsorship from 1964 to 1967, two vessels were used. In the first, steam and coal were reacted in a molten-salt bath to yield synthesis gas. In the second vessel, the residual carbon in the circulating molten carbonate was burned with air to reheat the sodium carbonate for recirculation. Because of problems arising from the corrosive nature of the salt, the small-scale tests of this process, were discontinued.</p> <p>W.M. Kellogg Co., continued their research and developed a noncorrosive alumina reactor lining to overcome the corrosion problem, and incorporated the use of a single reactor vessel, which not only eliminates circulation of the molten salt, but also simplifies gas handling and reduces further processing requirements.</p>

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
Molten Salt (Cont'd.)						Because of these new developments, the Office of Coal Research sponsored additional work, with special emphasis on the suitability of the process as a method for generating a fuel gas suitable for magneto-hydrodynamic generating systems. The process is now being tested in a process development unit 10 times larger than earlier vessels.
Multiple Catalyst	Univ. of Wyoming Laramie, Wyo.	Methane is produced directly from coal and steam with the methanating catalyst bed placed in the middle of the reactor and heated to the desired temperature by a Lindberg furnace. The temperature is monitored by thermocouples located in the thermo-well inside the reactor. The methane-rich product gas passes through a motor valve which allows the pressure to be controlled.				The concept was developed at the Univ. of Wyoming and supported for 5 years by OCR. Babcock and Wilcox have undertaken further development of a better catalyst system, which could assure long catalyst life. The U.S. Bureau of Mines has conducted bench-scale experiments on the catalytic reaction of coal and steam at 1,900°F using tungsten-sulfide as a catalyst.
Self-Agglomerating Ash	Battelle Memorial Institute, Columbus Laboratories, Columbus, Ohio	Coal is reacted with steam in a two-stage fluidized-bed system. Air is used for combustion of part of the coal to provide heat for the gasification process. The process operates at up to 100 psi to produce a synthesis gas suitable for conversion to high-Btu pipeline gas by methanation.	Bituminous	25	0.8	Construction of the process development unit was completed in mid-1976, and shake-down started. The unit will be operated through mid-1977. The process engineering and economics data generated will be used to design a larger unit.
Synthane	U.S. Bureau of Mines, Pittsburgh Energy Research Center, Bruceton Pa.	Coal is fed into a reactor incorporating three processing steps: a free-fall oxygen-steam pretreatment zone, a dense fluid-bed carbonizer, and a dilute fluid-bed gasifier. Hydrogen-rich gas for the reaction is produced by the use of oxygen in the reactor. The process operates at 500 to 1,000 psia. The product gas can be purified and methanated to produce high-Btu gas.	All U.S. coals	70 (pilot plant)	1.4	Pilot plant design and construction were completed in 1975 and are currently in the shakedown phase. The plant is being operated to obtain enough data for designing a commercial plant.

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
Two-stage Fluidized Gasification	Midlands Research Station, United Kingdom	Coal is subjected to hydrogenation in two stages: a rapid reaction at 1,470°F-1,560°F and a slower reaction at 1,650°F-1,740°F at 750 psi. The char produced then passes to a fluidized-bed gasifier operating at 1,900°F, which produces a gas which is upgraded by catalytic methanation to pipeline quality.				Work has been done using fluidized-bed models under different operating conditions. From the results, a pilot plant to produce 4 million scf/day of synthesis gas was designed.
Wellman-Galusha	McDowell-Wellman Co. and Wellman-Galusha Co.	Crushed coal, dried and fed by an oxygen-steam mixture, is introduced through a revolving grate at the bottom of the reactor. Gasifiers are available with or without an agitator, which reduces channeling and maintains a uniform bed. The ash is removed continuously through a slowly revolving grate at the bottom of the reactor. The gas produced can be upgraded to high-Btu gas.				The process has been commercial for over 30 years. Two units are operating in the U.S. serving large industrial plants. McDowell-Wellman Co. is under contract to determine the feasibility of constructing a fixed-bed gasifier for operation on caking coals.
Winkler	Davy Powergas, Inc. Lakeland, Florida	Crushed coal is dried and fed to a fluidized bed gasifier through a variable-speed screw feeder. Coal reacts with oxygen and steam to produce offgas rich in carbon monoxide and hydrogen. Because of the high temperatures, all tars and heavy hydrocarbons are reacted. Unreacted carbon carried over by gas is converted by secondary steam and oxygen in the space above the fluidized bed. Flaw gas leaving the gasifier is passed through a further waste-heat recovery section. Fly-ash is removed by cyclones, wet scrubbers, and an electrostatic precipitator. Gas is then compressed, shifted, purified, and methanated.				The process has been in use commercially at 16 plants in a number of countries since its development in Europe 50 years ago. The plants produce low-Btu fuel gas and synthesis gas. Davy Powergas, Inc., is currently developing a high-pressure modification of the Winkler process which should increase the thermal efficiency.

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
Medium- and Low-Btu Processes						
Advanced System	Westinghouse Electric Corp. Pittsburgh, Pa.	Crushed, dried coal is fed into a central draft tube of a devolatilizer-desulfurizer. Coal and recycled solids are carried upward from a combustor by hot gases flowing at a velocity greater than 15 feet per second. Recycle solids flow downward in a fluidized bed surrounding the draft tube at rates up to 100 times the coal feed rate. Heat is provided by hot combustor gases. A lime sorbent is added to the gasifier to remove sulfur. Spent sorbent is removed, stripped of char, regenerated, and recycled to the gasifier. Char is removed from the top section of the gasifier and fed to the combustor. Raw product gas passes through a cyclone to remove fines and then through a heat-recovery unit.				This process is being tested in a 1,200 lb/hour pilot plant at Waltz Mill, Pa. Westinghouse, in late 1972, began a 9-year research and development program expected to cost \$80 million, cosponsored by Bechtel Corp., AMAX Coal, Peabody Coal Co., and the Public Service Co. of Indiana. Eleven electric power utilities are also sponsoring the program as associate members. A 60-ton/hour commercial, low-Btu gasification and electric power plant is under construction at the Dresser Station of the Public Service Co. of Indiana at Terre Haute, Indiana. This project, sponsored by ERDA, will utilize a combined-cycle coal gasification-power system fueled by the Westinghouse gasifier. The plant is expected to be operational during 1978.
BCR Fluid-bed Three-stage Pressurized	Bituminous Coal Research Monroeville, Pa.	This process consists of three fluidized beds. Raw coal is fed into Stage 1. This stage acts as a pretreatment stage, devolatilizing the coal with the offgas from Stage 3. From Stage 1 the coal flows by gravity to Stage 2 where it is gasified with air and steam. Stage 3 functions as a char combustion step, operates at the highest temperature, and maximizes char utilization.	All U.S. coals	1		Construction of a one-ton per day process development unit was completed late in 1975. The unit will be operated for two years, and will be used to study and optimize the multistage system. Data generated from operation will be used for scale-up design. Laboratory research has been done to further refine the process.
Combined Cycle	Babcock & Wilcox Co. Alliance, Ohio	Coal and air are fed to a pressurized, water-cooled gasifier where they react to form a combustible gas. After cleaning, the gas is fired in a combustor that discharges to a high temperature gas turbine, which, in turn, exhausts to the steam generating portion of the cycle to power a steam turbine generator.				A 480 ton/day pilot plant is planned to be installed at a power generation utility site yet to be selected. Testing in a 60 ton/day plant has been under evaluation since 1961.

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
Combined Cycle	Foster-Wheeler Corp., Livingston N.J.	The process utilizes an entrained-bed, two-stage slagging pressure gasifier. The low-Btu fuel gas produced by the reaction of coal, steam, and air is cleaned and fired in a combustor that discharges to a gas turbine. The hot gas expanding through the turbine is sent to the steam-generating portion of the cycle to power a steam-turbine generator.				A research and development program initiated in 1972 will culminate in the operation of a 1,200 ton/day demonstration plant at Northern States Power Co.'s Lawrence Plant near Sioux Falls, S.D. Foster-Wheeler is developing a detailed conceptual design of the demonstration plant.
Entrained Fuel	Combustion Engineering, Inc. Windsor, Conn.	The gasifier consists of two sections: a combustion chamber that burns coal and recycle char to provide heat to the gasifier, and a reducing chamber where coal is reacted with steam to produce low-Btu gas. The gasifier is an entrained-bed reactor operating at atmospheric pressure. The product gas with a heating value of 125 Btu/scf leaves the gasifier at 1,600°F and enters the heat-recovery train. The gas is cooled further to 300°F.		120		A 120 ton/day plant is being built and is scheduled for completion in 1977. The plant will be operated to determine the technical and economic feasibility of the process. Continuous operation will be attempted to demonstrate equipment reliability. Cost and performance estimates for a commercial-size plant will be determined.
Fixed Bed	M. W. Kellogg Co., Piscataway	This process uses a low pressure fixed-bed, revolving grate gasifier to produce a low-Btu fuel gas with air, and a medium-Btu fuel gas with oxygen. By-product tar and oil are used as plant fuel or chemical feedstock.				The company is presently studying the formation of a consortium to erect a demonstration plant at an, as yet, unselected utility site.
GE GAS	General Electric Research and Development Center, Schenectady, N.Y.	This process utilizes a moving fixed bed air-blown gasifier operating at 120 psi and 1,000°F. An extrusion process is used for coal feeding and off-gases are cleaned of hydrogen sulfide.				The process has been tested at a 50 lb/hour facility. A pilot plant will be built at a utility site. G.E. will initiate construction and operation of a pilot-plant heat exchanger to determine the effects of high-temperature coal gasification products discharging through an MHD generator.

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
HRI Fluidized Bed	Hydrocarbon Research, Inc. Princeton, N.J.	Steam and oxygen fluidize a bed with a fuel depth of 25 feet operating at pressures up to 400 psia, and at 1,450°F to 1,650°F to produce a synthesis gas of 320 Btu/scf.				Work was done in the 1960s using a 26-inch diameter fluidized-bed gasifier.
Kerpely Producer	U.S. Bureau of Mines, Louisiana, Missouri	Coal passes through a lock hopper down into a fixed-bed cylindrical unit, and is gasified by a steam-oxygen (or air) blast through a revolving grate, which remove the ash continuously. The unit operates at atmospheric pressure to produce a 260 Btu/scf gas with oxygen or a 130 Btu/scf gas with air.				A 7-foot internal diameter unit was operated by the U.S. Bureau of Mines. About 2 million scf/day of 260 Btu/scf synthesis gas with oxygen blasts were produced.
Molten Salt	Atomics International Norwalk, Conn.	Coal is gasified in a molten pool of sodium carbonate sulfide and sulfate through which air is blown. The product gas has a heating value of 150 Btu/scf. Conducting gasification reactions in the molten salt medium permits the attainment of very high oxidation rates and traps ash and sulfur in the melt.	All U.S. coals			Development tests, including hydraulic, quench tests, ash settling, solubility characteristics and regeneration of the molten salt, were conducted in FY 1975. A 24 ton/day process development unit has been designed.
Ruhrgas Vortex	Ruhrgas A.G. West Germany	High-ash coal or lignite, crushed to a 1/16-inch top size, is fed with air, preheated to 1,300°F, into a vortex chamber where it is gasified without steam and under slagging conditions. The slag passes out the bottom and the reactants pass upward into a tall shaft of larger diameter where the greater part of the gasification occurs at 3,100°F. The 100-120 Btu/scf off-gas is passed through cyclones and bag filters for dust removal and recycling of entrained gas.				The process has been in commercial use for many years to produce low-Btu fuel gas.

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
Stirred Fixed Bed	U.S. Bureau of Mines, Pittsburgh, Pa.	Unsize coal is fed to the top of the gasifier, which operates at 300 psi. Steam and air are introduced below the grate at the bottom. The nominal steam: coal feed ratio is 1:2 and the air: coal ratio is 3:1. Gasifier temperatures range from 2,400°F just above the grate to 880-1200°F at the gas exit. A water cooled stirrer is used to control caking and eliminate voids. The product is low-Btu gas.	Bituminous Subbituminous Lignite	12		A low-Btu gasification process development unit is operating at Morgantown Energy Research Center. Continued operation of the gasifier at different pressures with different types and sizes of coal to determine maximum capacity will provide the necessary data for design scale-up and economic evaluation. Construction of gas scrubber, hydrogen sulfide removal, and full blown combustion/turbine subsystems will begin in FY 1977. Operation of the fully integrated process, consisting of gasifier, cleanup, combustion, and turbine, will begin in FY 1978.
Texaco Gasification	Texaco Development Co.	Pulverized coal, suspended in steam at 950°F, is fed into the top of a downflow cylindrical reactor, where it is gasified with oxygen to produce 280 Btu/scf gas. The unit operates at 260 psi and temperatures above the ash fusion point. The product gas and slag are removed at the base of the vessel.				This process has been tested in a down-flow plant and has also been utilized in the HYGAS pilot plant for producing hydrogen.
Two Stage (Submerged Coal Combustion)	Applied Technology Corp.	The process is based on the molten-iron gasification process with air/coal feed to yield a 185 Btu/scf offgas and is similar to the ATGAS/PATGAS process.				Testing has been carried out in short runs using a 2-foot internal diameter vessel. The U.S. Environmental Protection Agency is sponsoring a design study for a 50 to 100 MW power generating plant using the process low-Btu offgas.
Two-step Coal Pyrolysis	West Virginia University Morgantown, West Virginia	Coal is fed to a sand fluidized bed for pyrolysis at 1,400°F. Char produced is separated from effluent gas and reacted with air and steam in a gasifier to produce fluidizing gases for the pyrolyzer. A small quantity of raw coal is added to the gasifier char feed where the temperature is maintained at 1,900°F.	All U.S. coals			Feasibility has been demonstrated in bench-scale experiments using a 15-inch diameter fluidized bed reactor. A conceptual study has been made of the process for application in power generation by coupling this process with an advanced-design combined gas and steam turbine power cycle.

Table IV-6 Cont.

GASIFICATION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor and Site	Process Description	Coal Type	Input (Tons/day)	Output (10 ⁶ scf/day)	Status
U-GAS	Institute of Gas Technology	Crushed coal is pressurized in a lock hopper operating at 350 psi and 800° F, reacted with air, and fed to a fluidized-bed gasifier operating at 350 psi and 1,900° F. Air and steam are introduced through the base of the gasifier and ash removed through lock hoppers. Gases from the preheater and gasifier pass through heat-recovery and sulfur removal systems and power-recovery turbines. Gas produced has a heating value of 155 Btu/scf. Substituting oxygen for air produces a medium-Btu fuel gas.				<p>The process has been tested in an air-blown 485 lb/hour unit, which showed the suitability of the process for both combined-cycle power generation and as a "grass-roots" source of industrial and power generation energy.</p> <p>A 10 to 35 ton/hour pilot plant, sufficient to fuel a 100 MW power utility, is being designed.</p>

Sources: *Coal Conversion Technology: A review*, I. Howard-Smith and G. J. Werner, 1975, and *Fossil Energy Research Program of the Energy Research and Development Administration*, FY 1977, ERDA 76-63.

Figure IV-4
FUEL GAS FROM COAL

Source: Oil and Gas Journal, August 26, 1974.

Figure IV-5

LIQUID FUELS FROM COAL

Source: *Energy From Coal, A State-of-the Art Review*, U.S. Energy Research and Development Administration, ERDA 76-67.

Table IV-7
LIQUEFACTION PROCESSES AND STATUS

Process	Owner or Contractor, Site, and Capacity	Process Description	Status
Bergius	None	Finely ground coal is mixed with process-derived hydrocarbon liquid and a catalyst. The mixture is reacted with hydrogen at 3,000 psi to 10,000 psi. The products from the first reactor are separated into light, middle, and bottom fractions. The middle fraction is further treated over a catalyst in a vapor phase to produce petroleum like products.	In the 1950s, a large government ammonia plant in Louisiana, Mo., was converted into two liquefaction demonstration plants, one of which used the Bergius process to produce about 200 barrels per day of gasoline. No Bergius plants are currently operating.
Catalytic Coal Liquefaction	Gulf Research and Development Co. 1 ton/day pilot plant	Dried and pulverized coal is mixed with a process-derived oil. The resultant slurry is forced through an arrangement of fixed catalysts by a stream of hydrogen at about 2,000 psi. The liquid product can be used for producing gasoline, diesel fuels, or petrochemical feedstocks.	Gulf Research and Development Co. has been testing this process for 8 years on a bench-scale level. In January 1975, the 1 ton/day pilot plant began operation. It is designed to yield 3 barrels of oil from each ton of MAF coal. A conceptual design of a larger demonstration plant is being prepared based on data from pilot plant operations.
Char-Oil Energy Development (COED)	FMC Corp. Princeton, N.J. 36 ton/day pilot plant	Coal is crushed and dried, then heated to successively higher temperatures in a series of fluidized-bed reactors. The temperature of each bed is just short of the maximum temperature to which coal can be heated without agglomerating and defluidizing the bed. The number of stages and temperatures vary with the agglomerating properties of the coal. The volatile matter released from the coal in the pyrolysis reactor is condensed in a product-recovery system.	The pilot plant has been operational since 1970. Only large-scale gasification of the pyrolysis char product remains to be demonstrated. A preliminary estimate has been made for a 24,000 ton/day COED plant to produce 26,400 barrels of oil per day, 12,000 tons of char per day, and 390 million scf of synthesis gas (400 to 500 Btu/scf) per day.
Clean Coke Process	U.S. Steel Corp. Monroeville, Pa. Five 500 lb/day process development units 100 ton/day pilot plant being designed 17,000 ton/day commercial plant planned	Coal, after beneficiation and sizing in a coal preparation plant, is split into two fractions: part is processed through a carbonization unit where it is devolatilized, and the remainder is slurried with a process-derived carrier oil and is hydrogenated to convert a large portion of the coal to liquid. The liquid products from both units are converted into low sulfur liquid fuels, chemical feedstocks, and three oil fractions that are recycled into other areas of the process.	Design and operation of the five 500 lb/day process development units is planned by 1977. Bench-scale studies to aid design and operation of these units are being conducted, and a 100 ton/day pilot plant is being designed. The planned commercial plant will produce, annually, 2.2 million tons of coke, 669,000 tons of oil residue, 750,000 tons of chemical products, 34,000 tons of ammonia, 49,000 tons of sulfur, 80 million gallons benzene, and 8 million gallons of tar products.
Coal-Oil-Gas (COG) (Liquefaction section)	Pittsburg & Midway Coal Mining Co. Merriam, Kansas	Crushed coal is combined with unfiltered solvent to produce a 50 weight percent slurry, which is sent to the preheat furnace. The slurry is combined with	The Ralph M. Parsons Co. was awarded a contract for designing a COG demonstration plant, based on design data supplied by the individual process

Table IV-7 Cont.

LIQUEFACTION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor, Site, and Capacity	Process Description	Status
COG (cont'd)	6 ton/day pilot plant 50 ton/day pilot plant	synthesis gas and water, then fed to the reactor. The solid phase is separated by filtration from a portion of the liquid phase, and is transferred to the gasification plant. The filtrate is fractionated to produce naphtha, distillate that is desulfurized to a higher boiler fuel, and residual fuel oil. Solid solvent-refined coal can be produced by distillation if required.	developers. This demonstration plant is designed to process 10,000 tons of coal feed per day to produce 2,011 barrels of naphtha, 8,472 barrels of fuel oil, 11,345 barrels of heavy liquid product, 121 tons of heavy liquid plant fuel, 2,142 tons of fuel gas, and 317 tons of sulfur per day.
COGAS	COGAS Development Co. Princeton, N.J. 36 ton/day pyrolysis pilot plant 50 ton/day char heat-carrier pilot plant	Gasification combustion of coal is integrated with multistage fluidized-bed coal pyrolysis. The products of pyrolysis are a reactive char and pyrolysis oil and gas. The char is sent to the gasifier; the oil can be upgraded by hydrogenation to a high-grade synthetic crude oil or, by using less hydrogen, to a low-sulfur fuel oil.	The pyrolysis section of the process is based on the COED process. The pilot plants at Leatherhead, England, and Princeton have successfully demonstrated most of the key features of the COGAS process, and are providing design data for an 800 to 1,000 ton/day demonstration pilot plant.
Consol Synthetic Fuel (CSF)	Consolidation Coal Co. Cresap, W.V. 20 ton/day pilot plant 900 ton/day demonstration plant planned	Crushed coal is preheated in a fluidized bed to 450° F, then slurried in process-derived solvent. The slurry is pumped to a stirred solvent-extraction vessel where extraction occurs at 765° F and 150 to 400 psi. Recycle solvent, distillate, and liquid product for hydrotreatment to naphtha are produced. Solid residue in a concentrated slurry is sent to a low temperature carbonization reactor where the slurry is pyrolyzed at 800° F to 900° F and low pressure to recover the solvent and also to produce additional distillate by coking the residue and the extract. In the hydrotreatment section, liquid product from the fractionation step and tar from the carbonization step are hydrogenated in a catalytic reactor operating at 800° F and 3,000 psi to produce naphtha, light oil, gas, and makeup solvent.	This process was tested in the pilot plant from 1967 to 1970. The results were less favorable than predicted, based on bench-scale tests. A detailed assessment of the process indicated that it was technically sound but that major mechanical modifications were necessary to improve operating reliability. In 1974, Fluor Corp. was awarded a 3-year contract to re-vamp the Cresap pilot plant and supplement existing equipment with new equipment designed to produce fuel oil for power generation and industrial uses. The plant may also be modified to evaluate several coal liquefaction processes for various types of coals.
Exxon Liquefaction	Exxon Research and Engineering Co. Baytown, Texas 0.5 ton/day laboratory unit	Crushed coal is slurried with a recycle solvent, preheated to about 800° F, and pumped into the liquefaction reactor operating at about 2,000 psi. Pre-treated hydrogen is also added to the reactor. The product is separated into gas, naphtha, recycle solvent, distillate, and heavy bottoms. The recycle solvent is catalytically hydrogenated and slurried with fresh coal to repeat the cycle.	Laboratory work on this process has been done since 1966. Exxon recently proposed government funding of a planned 200 ton/day plant for demonstrating critical process features.

Table IV-7 Cont.

LIQUEFACTION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor, Site, and Capacity	Process Description	Status
Fischer-Tropsch Synthesis	South African Coal, Oil, and Gas Corp., Ltd. (SASOL) 6,600 ton/day commercial plant 38,000 ton/day commercial plant	In the SASOL Fischer-Tropsch plant, coal is gasified in 13 Lurgi high-pressure, steam-oxygen gasifiers. The gas produced consists primarily of carbon monoxide and hydrogen. The gas is quenched to remove tar and oil and purified by the Rectisol (Lurgi) process. Part of the gas is passed through a fixed bed catalytic reactor (Arge synthesis). The products are straight-chain high-boiling hydrocarbons with some medium-boiling oils, diesel oil, L.P.G., and oxygenated compounds such as alcohols. The other portion of the gas goes to the Synthol plant (Kellogg synthesis), which is a fluidized-bed catalytic iron reactor. Products are gasoline, alcohol, oil, and gas.	The SASOL plant is the only one producing liquid hydrocarbons from coal-derived synthesis gas using the Fischer-Tropsch process. The plant has been operating since 1955, and produces about 2.5 million tons of petrochemicals per year. A second SASOL plant is planned, and should come on-stream in 1979-1981. This plant should produce about 10 million tons of gasoline per year. In the United States, the Ralph M. Parsons Co. was awarded a 3-year contract in 1974 that includes preliminary design work on a Fischer-Tropsch synthesis plant to produce substitute natural gas and motor fuels. ERDA's R&D program includes the preliminary design of a process development unit to evaluate modifications to the process.
Garrett's Coal Pyrolysis	Garrett Research and Development Co. La Verne, Calif. 3.6 ton/day pilot plant	Crushed coal, in a stream of recycled gas, is pyrolyzed at 1,100° F through contact with hot char from a char heater vessel. Effluent from the pyrolysis reactor is sent to a series of cyclones for separation of gas and entrained char. A portion of the char is cooled as product char. The remaining char is sent to the char heater where a portion is burned with air to heat the contents to 1,400° F. Hot char is cycled to the pyrolysis reactor. Part of the gas from the cyclones is cooled, scrubbed, and sent to a plant for generating hydrogen, which is used in the tar hydrotreater to produce liquid fuels.	Garrett Research and Development Co. has studied pyrolysis and gasification coal for years. Results to date indicate typical yields equal to 200 percent Fischer assay and significantly higher than fluidized-bed pyrolysis processes.
H-Coal	Hydrocarbon Research, Inc. (HRI) Trenton, N.J. 3 ton/day process development unit 600 ton/day pilot plant planned	Dried, pulverized coal is slurried with process-derived oil, then compressed hydrogen is added. The mixture is heated and fed to an ebullated-bed catalytic reactor. Vapor product from the reactor is cooled and cleaned to separate the heavier components as liquid. Light hydrocarbons, ammonia, and hydrogen sulfide are absorbed from the gas stream and sent to a separator and sulfur-recovery unit. Liquid-solid product from the reactor is fed into a flash separator. Material that boils off is distilled to produce light and heavy distillates. The bottoms product from the flash separator (solids and heavy oil) is further separated in a vacuum still to produce heavy distillates and residual fuel oil.	HRI has been developing the H-Coal process since 1964, based on experience with the H-Oil process. Various plant options and systems have been developed and tested. The cost of the 600 ton/day demonstration pilot plant is expected to exceed \$80 million; the government will provide two-thirds of the project cost.

Table IV-7 Cont.

LIQUEFACTION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor, Site, and Capacity	Process Description	Status
Intermediate Hydrogenation	University of Utah Salt Lake City, Utah 50 lb/hour bench-scale unit 5-10 ton/day pilot plant designed	Dry, pulverized coal is passed with catalyst stannous or zinc chloride into a reactor containing hydrogen at 2,000 to 2,500 psi. The coal is hydrogenated, and liquid fuels and gases are produced.	Successful research and development work on the process was conducted between 1969 and 1974. The University has also experimented (bench-scale) on catalytic hydrosolvation of coal and lignite to synthesize crude in a single step.
Project SEACOKE	ARCO Chemical Co. Philadelphia, Pa. Laboratory unit 10,000 barrel/day pilot plant designed	Coal, usually blended with petroleum residuum as part of the feedstock, is pyrolyzed in multistage fluidized beds to produce char, liquids, fuels, and gas. After separation of the phases, the liquid products are further catalytically hydrotreated to produce gasoline. The gas can be used in the process or sold, and the char can be used for power generation on site.	This project was operational under government sponsorship during the 1960s. A 10,000 barrel/day plant was designed for converting coal and residual fuel oil to char, syncrude, and fuel gas. In 1970, the final report on the project was issued.
Solvent-Refined Coal (SRC)	Pittsburgh & Midway Coal Mining Co. (PAMCO) Merriam, Kansas 50 lb/hour continuous flow process development unit 6 ton/day pilot plant 50 ton/day pilot plant 1,000 ton/day demonstration plant planned	Pulverized coal is slurried with coal-derived solvent, then hydrogen (produced by other steps in the process) is added. The mixture is pumped through a fired preheater and passed into a dissolver where about 90 percent of the MAF coal is dissolved. Gas is then separated from the slurry of undissolved solids and coal solution. The raw gas is sent to a hydrogen-recovery and gas-desulfurization unit. The undissolved solids are separated from the coal solution in a filtration unit. The coal solution passes to the solvent recovery unit and the final liquid product, solvent-refined coal, is produced.	Beginning in 1972, Spencer Chemical Co. (subsequently PAMCO) conducted bench-scale evaluation of the Pott-Bruche process to find a clean fuel. The project has continued at an accelerated pace and much interest has been shown by both government and private companies. In 1974, Wheelabrator-Frye announced plans for a 1,000 ton/day demonstration plant costing \$80 million. If successful, the plant can be expanded, over 3 years at a cost of about \$350 million, to 10,000 tons/day.
Synthon	U.S. Bureau of Mines, Pittsburgh Energy Research Center Pittsburgh, Pa. 5 lb/hour bench-scale unit 0.5 ton/day pilot plant 8-10 ton/day pilot plant under construction	Pulverized, dried coal is slurried with recycled oil. The slurry is pumped into a catalytic, fixed bed reactor with hydrogen at high velocity to create turbulent flow conditions. The reactor is filled with immobilized catalyst pellets composed of cobalt molybdate on silica-activated alumina. The hydrogen, turbulent flow conditions, and catalytic action combine to liquefy and desulfurize the coal. The product passes through a high-pressure receiver where gas is separated and recycled after ammonia and hydrogen sulfide are removed. The raw oil is	Progressing from a bench-scale unit and a small pilot plant, the Bureau of Mines awarded a \$6.9 million contract to Foster Wheeler Corp. to procure equipment and construct an 8 to 10 ton/day pilot plant (producing 1,000 gallons of fuel oil per day). Bethlehem Steel Corp. will contribute \$1.1 million to the plant's cost and \$0.5 million for further research, and will operate the pilot plant for 2 years. If the project is successful, a 700 ton/day plant will probably be constructed.

Table IV-7 Cont.

LIQUEFACTION PROCESSES AND STATUS (Cont'd)

Process	Owner or Contractor, Site, and Capacity	Process Description	Status
Synthoil (cont'd)	700 ton/day demonstration plant being designed	centrifuged to remove ash and unreacted coal, providing a low-sulfur, low-ash fuel oil.	
Toscoal	The Oil Shale Corp. (TOSCO), Rocky Flats Research Center Golden, Colorado 25 ton/day pilot plant	Preheated coal from a dilute-phase fluidized bed is fed to a pyrolysis vessel where it is contacted with heated ceramic balls. The char produced in this reactor is screened, cooled, and stockpiled. The cooled ceramic balls pass over the screen and are reheated. The vaporized products of the pyrolysis step are condensed and fractionated. Offgas (600 Btu/scf) from the condenser can be used as a fuel gas heating the ceramic balls or processed for sale.	TOSCO has investigated the Toscoal process since 1970, drawing on experience and development work associated with the TOSCO II process for oil-shale retorting. The TOSCO II process was field tested in a 1,000 ton/day pilot plant, and construction engineering is under way on a 66,000 ton/day commercial oil-shale plant. The Toscoal process will probably parallel development of the TOSCO II process in the future.

Sources: I. Howard-Smith and G. J. Werner, *Coal Conversion Technology: A Review*, 1975.

Energy From Coal, A State-of-the-Art Review, U.S. Energy Research and Development Administration, ERDA 76 67.

Fossil Energy Research Program of the Energy Research and Development Administration, FY 1977, ERDA 76 63.

Table IV-8

SYNTHESIS GAS PROCESS

Process	Reactor Bed Type	Temperature (° F)	Pressure (psig)	Reactants	Products
Fischer-Tropsch Synthesis					
M. W. Kellogg (SASOL)	Fluidized-bed catalytic	620	330	Synthesis gas Iron catalyst	Gasoline, alcohol, oil, gas
Arge-Arbeit (SASOL)	Fixed-bed catalytic	450	360	Synthesis gas Iron/cobalt catalyst	Gasoline, L.P.G., oil, wax, gas

Source: I. Howard-Smith and G. J. Werner, *Coal Conversion Technology: A Review*, 1975.

Table IV-9

PYROLYSIS PROCESSES

Process	Reactor Bed Type	Temperature (° F)	Pressure (psig)	Reactants	Products
Char-Oil Energy Development (COED) (FMC Corp.)	Fluidized bed No. 1	600	5-10	Coal Heat	Char, oil, gas, liquor
	No. 2	850	5-10		
	No. 3	1,000	5-10		
	No. 4	1,500	5-10		
COGAS (COGAS Development Company)	Four fluidized beds	600-1,500	5-10	Coal Heat	Char, oil, gas, liquor
Garrett's Coal Pyrolysis (Garrett Research and Development Company)	Pyrolyzer	1,100	Atmospheric	Coal Hot char	Tar, product char, gas
Project SEACOKE (ARCO Chemical Company)	Five fluidized beds	600-1,600	Atmospheric	Coal Heat	Char, gas, oil
TOSCOAL (TOSCO)	Pyrolyzer	800-1,000	Atmospheric	Coal Heat	Char, gas, oil

Source: I. Howard-Smith and G. J. Werner, *Coal Conversion Technology: A Review*, 1975.

Table IV-10

HYDROGENATION PROCESSES

Process	Process Type	Temperature (° F)	Pressure (psig)	Reactants	Products
Bergius (F. Bergius)	Solution Hydrogenation (Iron-oxide catalyst)	900	3,000-10,000	Coal Recycle oil Hydrogen	Light oils
Catalytic Coal Liquefaction (Gulf Research and Development Company)	Fixed-bed catalytic	900	2,000	Coal Oil Hydrogen	Synthetic crude oil, gas
Clean-Coke Process (U.S. Steel Corp.)	Carbonization	1,200-1,400	100		Liquid products, gas, char for coker
	Extraction Hydrogenation	900	3,000-4,000		Liquid products, gas, filter cake for gasifier
Coal-Oil-Gas (COG) (Pittsburg & Midway Coal Mining Company)	Extraction Hydrogenation	850	1,000	Coal slurry Synthesis gas Water	Naphtha, fuel, oil, SRC, fuel gas
Consol Synthetic Fuel (CSF) (Consolidation Coal Company)	Extraction	765	150-400		Vapors, liquids, residue
	Carbonization	925	10		Char, pyrolysis, liquid, gas
	Hydrotreatment	800	3,000		Naphtha, oil, gas, residue
Exxon Liquefaction (Exxon Research and Engineering Company)	Catalytic Hydrogenation	800	2,000	Coal H-Donor solvent Hydrogen	Naphtha, gas, distillate, heavy bottoms, recycle solvent
H-Coal (Hydrocarbon Research, Inc.)	Emulsified-bed catalytic	850	2,250-2,700	Coal Oil Hydrogen	Synthetic crude oil, gas
Intermediate Hydrogenation (University of Utah)	Entrained-flow catalytic	930-1,020	2,000-2,500	Coal Hydrogen	Liquid, gas
Solvent-Refined Coal (SRC) (Pittsburgh & Midway Coal Mining Company)	Dissolver	815	1,000	Coal Hydrogen Solvent	Solvent-refined coal
Synthoil (U.S. Bureau of Mines, Pitts- burgh Energy Research Center)	Fixed-bed catalytic	850	2,000-4,000	Coal Hydrogen Oil	Fuel oil, gas

Source: I. Howard Smith and G. J. Werner, *Coal Conversion Technology: A Review*, 1975.

The only commercial coal liquefaction operation is the Fischer-Tropsch plant in South Africa (a second, larger plant is currently under construction). This plant's technology is based on the conversion of the carbon contained in coal to carbon monoxide through the injection of oxygen and steam followed by catalytic hydrogenation of the carbon monoxide to hydrocarbons.³ The Fischer-Tropsch technology is still expensive and consequently there is no development yet in the United States.

Coal Bed Gas Collection and In Situ Technologies.

These technologies are less developed in comparison to the coal gasification and liquefaction technologies. Coal Bed Gas collection technology consists of de-gasifying coal seams prior to mining. The end product is a commercially marketable natural gas product and also results in lower ventilation costs to the mining company and safer mining conditions.⁴

In situ technology is "simply another method of producing synthetic fuel from coal, tar sands and oil shale. First, channels are created in the coal bed of hydraulic fracture or explosives. Heat is then generated in the formation (usually by an underground fire). The heat generates either carbonaceous liquids or gases which move through the fracture channels to be recovered by a network of production on the surface. The major problem with this method is the links between the fractures and the production wells, i.e., only a portion of the production wells drilled will connect with a fracture and allow recovery of the fuel."⁵

Potential Application of Gasification and Liquefaction of Utah Coals

The following is the analysis of the Office of the State Science

Advisor:

While lignites and sub-bituminous coals can be converted to liquids, high volatile bituminous coals are generally considered to be superior for liquefaction. Whereas in gasification the structure is broken down completely to the single carbon atoms, in liquefaction one tries to obtain molecules containing several carbon atoms. Such molecules can more readily be produced from bituminous coals than from lignites. In gasification of coal to low-BTU gas, namely 150 to 325 BTU per standard cubic foot, the gaseous product cannot be used for many of the applications of natural gas. The gaseous product also cannot be economically transported over significant distances because of the low heating value. Every effort is thus exercised to keep the cost as low as possible. It is generally concluded that only coals mined by surface mining techniques at current actual mining costs around \$3.00 per ton can economically be gasified to low-BTU gas.

When coal is gasified to high-BTU or pipeline gas, with a heating value in the range of 900-1000 BTU per standard cubic foot, the potential market is much greater. This gas can be transported in pipelines over long distances, even 1000 to 2000 miles, and used interchangeably with natural gas. It is estimated today that such a gaseous product will be valued at \$4.00 to \$5.00 per thousand standard cubic foot. Actual mining costs for underground coal mining in Utah in 1976 are from \$8.00 to \$11.00 per ton of coal. Coal gasification processes utilizing bituminous coals could produce 250 million standard cubic feet of high-BTU gas from about 17,000 tons of coal. At a mining cost of \$10.00 per ton the mining cost represents 68 cents per 1000 standard cubic feet of gas. In other words, of the \$4.00 to \$5.00 production cost 68 cents is represented in the actual mining cost. Although some of the lower rank lignites and sub-bituminous coals can be surface mined cheaply (about \$3.00 per ton) the gaseous yield from these coals is considerably lower than that from bituminous coals requiring perhaps one-third to one-half more of the lower rank coal to equal the gaseous product yield of bituminous coal. For instance, the production of 250 million standard cubic feet of pipeline gas would require about 25,000 tons of lignite. Hence per 100 standard cubic feet of pipeline gas product the underground mining cost for bituminous coals is only 35 cents to 40 cents more than the mining costs represented in the surface mined lower rank coals. This is not a significant factor in relation to the price of the product.

A smaller disadvantage is realized in respect to bituminous coals in connection with liquefaction. The liquid product yield from bituminous coal is nearly twice as great per ton of coal as from lignite. It is also significantly greater than from sub-bituminous coal. In most liquefaction processes under development today, about 3 barrels of synthetic crude oil can be produced from one ton of bituminous coal. At \$10.00 per ton actual mining cost this translates to about \$3.30 per barrel. Even from the surface mined low rank coals at lower mining costs this would still be in

excess of \$2.00 per barrel. It is generally estimated that a synthetic crude from coal must be valued at \$25.00 to \$30.00 per barrel. Hence the difference in cost per barrel for a synthetic crude from bituminous coal as compared with lignite or sub-bituminous is very small. Very few, if any, developers are seriously considering the production of liquid fuels from lignite. Also, little attention is being applied to sub-bituminous coals for liquefaction.

It may thus be stated that whereas surfaced mined coals will generally be more suitable for the production of low-BTU gas, high volatile bituminous coals from an economic point of view as surface mined coals both for gasification to high-BTU gas and for liquefaction.

Most processes under development for the production of high-BTU or pipeline gas from coal initiate the process by producing a synthesis gas which is a mixture of carbon monoxide and hydrogen. This gas is produced by injecting oxygen and steam into the coal bed in a controlled manner such that most of the carbon in the coal is converted to carbon monoxide with very little appearing as carbon dioxide in the synthesis gas mixture. At the same time, the steam reacts with carbon producing hydrogen and carbon monoxide, usually also yielding some methane. The technology for doing this is essentially the same as the technology for producing a low-BTU gas. This gas is then subjected to a catalytic process for reacting the carbon monoxide with additional steam in what is known as the water-gas shift reaction. This process increases the ratio of hydrogen to carbon monoxide in the mixture. When this ratio is about 3:1 the mixture is then passed over a methanation catalyst to convert the mixture to methane.

It has been observed that the low rank coals, lignite and sub-bituminous coal, are somewhat more reactive toward this gasification process than are the higher rank coals. However, high volatile bituminous coals such as those in Utah are strongly reactive toward these reactions and are very well suited to gasification. Inasmuch as the initial reactions in the process involve controlled oxidation of the carbon in the coal at high temperature, these reactions will proceed with essentially any coal and many of the requirements for coal liquefaction are not requirements in coal gasification. It has been noted that the yield of pipeline gas per ton of coal is higher with the high volatile bituminous coals than with sub-bituminous coal or lignite because the high volatile bituminous coal contains less moisture and therefore more material per ton of coal which can be converted to methane.

The requirements for coal liquefaction are very different. The molecules of interest in the liquid product contain from six to twelve, or sixteen, or twenty carbon atoms per molecule, depending upon the desired liquid product, whereas for pipeline gas the molecule contains only one carbon atom per molecule. Hence in liquefaction one does not desire to break the coal structure into such small entities. Since the molecular structure tends to be broken into small entities at high temperature, temperatures for liquefaction are usually in the range of 450-500 C. Accordingly there is a great difference in the response of various coals to liquefaction reactions.

Perhaps the most useful characterization of coal for liquefaction is the petrographic analysis. To date very few petrographic analyses have been performed relative to the various coal deposits in Utah. One cannot at this time evaluate Utah's coals for liquefaction based upon petrographic analysis.

Another means of characterizing coals is known as coal rank. According to this system of classifying coals, anthracite is the highest rank followed by low volatile bituminous, medium volatile bituminous, high volatile bituminous, sub-bituminous coals and lignite. A principal factor in establishing the rank of a coal is the volatile matter content, which is determined by a standard ASTM test. High volatile bituminous coals usually contain from 35 to 45 weight percent volatile matter according to this test. While the rank of the coal, or its volatile matter content, is not nearly as accurate in predicting the suitability of a coal for liquefaction as petrographic analysis, it has been observed that in general high volatile bituminous coals are most suited to coal liquefaction based upon their reactivity toward liquefaction reactions and the yield of liquids per ton of coal. Therefore according to this standard most of the coals in Utah would be suitable as feed stocks for liquefaction.

Another property of coals related to suitability for liquefaction arises from the ultimate analysis of the coal which gives the composition of the coal with relation to five elements: namely, carbon, hydrogen, oxygen, nitrogen, and sulfur. Most bituminous coals which have been utilized for coal liquefaction in the various processes under development possess an atomic ratio of hydrogen to carbon of the order of 0.8 to 0.9. Many of Utah's coals possess an atomic hydrogen to carbon ratio between 0.9 and 1.0. A typical raw liquid product produced in the first stage of a coal liquefaction process has an atomic hydrogen to carbon ratio of the order of 1.1. One can see from these observations that the conversion of Utah coals with the high hydrogen content to a raw liquid involves less hydrogen input per pound of coal than most high volatile bituminous coals. This may represent not only a reduction in the amount of hydrogen required in this initial conversion step but may be related to the ease with which the coals can be converted to the raw liquid.

While Utah's coals have not been tested in all of the coal liquefaction processes, data are available as a basis of comparison between Utah coals and other coals in relation to the pyrolysis liquefaction process of FMC Corporation, known as COED, and the short residence time catalytic hydrogenation process under development at the University of Utah. In the COED process the Utah coals were observed to give liquid yields 10 to 20 percent higher than the liquid yields of most other coals. In the short residence time catalytic hydrogenation process, for a single pass under a given set of reaction conditions, Castle Gate, Utah coal from the Wasatch Plateau yielded 56 percent conversion, Kaiparowits, Utah coal yielded 45 percent conversion, and Illinois #6 yielded 30 percent conversion, all percentages by weight of liquids and gases. The ratio of liquids to gases was about 6 to 1. Whereas most high volatile bituminous coals have a hydrogen content in the range of 5 to 5.5 weight percent hydrogen, most of Utah's coals have hydrogen contents in the range of 5.5 to 6.0 weight percent with some ranging

as high as 6.3 to 6.4 weight percent hydrogen. There is thus a strong basis for concluding that Utah's coals will probably be more satisfactory for liquefaction than most other coals in the United States.

There are one or two other features of the composition of Utah's coals in relation to liquefaction and gasification to be discussed. Whereas most of the eastern coals which could now be made available for gasification or liquefaction have sulfur content in excess of 3 percent by weight, most of Utah's coals contain less than 1 percent sulfur. Large reserves of coals may be available with sulfur content as low as 0.5 percent sulfur. Since the sulfur must be removed from any gasification or liquefaction product, involving hydrogen consumption, these Utah coals are more desirable in this respect.

The ash content of Utah's coals also is an attractive feature. The ash is composed of organic material which itself cannot be converted to liquid or gaseous products, although there may be some beneficial features in the ash material such as catalytic activity. The ash content of Utah coals is generally between 4 to 8 percent by weight, which is moderate as far as bituminous coals are concerned. Since the ash represents a disposal problem, it is desirable that the ash content should not be too high.

A summary of the status planned or constructed coal fired electric generating plants is shown in Table IV-11.

Resource Development Requirements

The resource development requirements for coal-fired powerplants are presented in Table IV-12. The following criteria is useful in siting a coal-fired power plant: (1) engineering/economic criteria, (2) environmental criteria and (3) sociological criteria.

The coal requirement for a coal-fired generating plant using the Huntington and North Emery Generating Stations as data ranges from 1,950 to 2,900 tons of coal to produce 1 MW of electricity--annual production. (See Table IV-13.)

The water requirements for coal power plants are significantly related to the specific technology used in the conversion of coal.

However, water is required during the following stages of processing:

- (1) surface mine dust control, (2) surface mine rehabilitation, (3) coal beneficiation-washing, (4) generating plant cooling water, (5) coal

Table IV-11

**STATUS OF RECENTLY PLANNED OR CONSTRUCTED COAL-FIRED
ELECTRIC GENERATING PLANTS (AS OF AUGUST 1977)**

Generating Plants	Still Planned	Final EIS Completed	Concept Approval ^a	Construction Approval ^a	Presently Under Construction	Anticipated Time of Completion	Presently On-Line
Warner Valley Station (of the Allen-Warner Valley Energy System)	Yes	Yes	No (except in Fall of 1977)	No	No	None	No
Alunite Project	Yes	Yes	No	No	No	None	No
UP&L Plant near either Axtell or Nephi ^b	Yes	No	No	No	No	1984-1986	No
Emery Plant:							
1st Unit	Yes	Yes	Yes	Yes	Yes	June 1978	No
2nd Unit	Yes	Yes	Yes	Yes	Yes	June 1980	No
Huntington Plant:							
1st Unit	--	Yes	Yes	Yes	No	--	Yes (since '74)
2nd Unit	--	Yes	Yes	Yes	No	--	Yes (declared commercial in June 1977)
IPP*	Yes	No	No	No	No	None	No

*IPP has relieved project approval from the U.S. Department of Interior.

^a Concept approval is given by the State of Utah based on the final EIS. Construction approval is also given by the State based on the actual plant construction plans.

^b Many other sites are also under consideration.

Source: Interview with Dr. Val Finlayson of Utah Power & Light and Utah Department of Social Services, Division of Health.

Table IV-12

Summary of Relevant Power Plant Siting Criteria

I. Engineering/Economic Criteria

A. Geologic Factors

1. Faulting With a Potential For Surface Displacement in or Adjacent to a Cell
2. The Presence of Soluable or Unstabel Minerals Beneath or Adjacent to a Cell
3. The Presence of Large Voids in the Subsurface Within or Adjacent to a Cell.
4. The Presence of Thick Coal Feds Beneath a Cell
5. Sloping Stability
6. Mining and/or Fluid Withdrawal
7. Seismicity

B. Soil Foundations

1. Bearing Capacity
2. Settlement Characteristics
3. Potential for Liquefacation
4. Depth to Bearing Stratum
5. Possible Need for Piles or Caissons

C. Rock Foundation

1. Rock Strength and Homogeneity
2. Presence of Voids or Cavities Requiring Treatment
3. Presence of Sheared or Other Weak Zones Requiring Treatment
4. Deterioration of Rock After Exposure
5. Presence of Soluable or Unstable Minerals Which May Affect the Stability of the Foundation

D. Site Development

1. Rough Grading Needed to Level and Prepare a Plant Site
 - a. Quantity of Material to be Moved
 - b. Workability of Material
 - c. Size of Dams or Dikes
 - d. Lining
 - e. Pumping Head
 - f. Pipeline Length

E. Fuel Supply and Access

1. Fuel Costs
 - a. Coal Characteristics
 - b. Required Annual Tonnage

Table IV-12
(continued)

- 2. Fuel Delivery
 - a. Distance and Freight Costs
 - b. Mode of Delivery
 - c. Upgrading of Existing System
- 3. Site Access
 - a. Access Road Length
 - b. Rail Spur Length
- F. Site Access
- G. Water Supply
 - 1. Water Source and Delivery
 - a. Intake Structure and Pumping Plant
 - b. Pipeline Size and Installation
 - c. Distance to Water Source
 - 2. Water Treatment and Storage
 - a. Source Quality
 - b. Source Reliability
 - c. Surge Pond Distance to the Plant
 - d. Dams or Diking Requirements
 - e. Requirement for Surge Pond
 - f. Pumping Head
 - g. Requirement for Booster Stations
 - h. Availability of Surge Pond Sites
- H. Air Quality Maintenance
 - 1. Flue Gas Desulfurization and Particulate Control Equipment
 - a. Coal Characteristics
 - b. Boiler Design and Operation
 - c. Emission Control Regulations
 - 2. Stack and Flue Gas Design
 - a. Atmospheric Dilution Potential
 - b. Surrounding Topography
 - c. Stack Weight
 - d. Flue Gas Characteristics
 - e. Flue Gas Exit Velocity
 - f. Ambient Air Quality Standards
 - g. Total Emissions

Table IV-12
(continued)

I. Transmission System

1. Transmission Line Distance

- a. New Line Construction
- b. Upgrading the Existing Line, When Required
- c. Power (I²R) Losses
- d. Property For New and Expanded Rights of Way

2. Associated Facilities

- a. Generation Plant Facilities
- b. Substations
- c. Miscellaneous Facilities
- d. Synchronous-Resonance Protection

J. Proximity of Hazards

- 1. Airfields
- 2. Existing Pipelines
- 3. Operating Oil Wells
- 4. Operating Quarries

K. Property Availability

1. Present Land Ownership

- a. Indian Reservations
- b. Federal Resource Land
- c. State Owned Land
- d. Privately Owned Land

2. Current Land Use

- a. National Reserves--Parks and Monuments
- b. Public Recreation Lands
- c. Urban Communities

L. Labor Force

1. Wage Incentives

- a. Relocation Allowances
- b. Travel Allowances
- c. Wage Additives

Table IV-12
(continued)

2. Community Support Capacity
 - a. Services and Facilities
 - b. Housing
 - c. Population
3. Labor Availability
 - a. Types of Crafts
 - b. Size
 - c. Residence
 - d. Operation Work Force

II. Environmental Criteria

A. Terrestrial and Aquatic Ecology

1. Terrestrial Ecology
 - a. Range Conditions
 - b. Unique Species
 - c. Population Density of Game Animals
 - d. Overall Biota Diversity
2. Aquatic Ecology
 - a. Quantity of Habitat
 - b. Value to Fish
 - c. Value to Wildlife
 - d. Fishing Potential
3. Threatened or Endangered Species
 - a. Flora
 - b. Fauna

B. Atmospheric Effects

1. Plume Visibility
 - a. Frequency
 - b. Color
 - c. Location
 - d. Dimensions
2. Effects on Ecology
 - a. Salt Drift

Table IV-12
(continued)

- b. Odor
- c. Fugitive Dust
- d. Water Vapor

3. Safety and Convenience

- a. Ground Fogging Frequency
- b. Icing Frequency

C. Noise

1. Construction Noise Effects

- a. Population Density
- b. Population Proximity
- c. Population Response to Noise
- d. Duration of Construction Activities
- e. Construction Noise Levels
- f. Major Transportation Routes

2. Operating Noise Effects

- a. Population Density
- b. Population Proximity
- c. Population Response to Noise
- d. Operating Plant Noise Levels
- e. Transportation-Related Noise Levels
- f. Major Transportation Routes

III. Sociological Criteria

A. Land Use

1. Present Land Use Compatibility With Project

- a. Urban Areas
- b. Mineral Reserves
- c. Recreation Areas
- d. Wildlife Preserves
- e. Indian Reservations
- f. Other Special Interest Areas

2. Planned Land Use Compatibility With Project

- a. Urban Areas
- b. Mineral Reserves
- c. Recreation Areas
- d. Wildlife Preserves
- e. Indian Reservations
- f. Other Special Interest Areas

Table IV-12
(continued)

3. Cultural Resource Characteristics

- a. Degree of Disturbance
- b. Complexity and Uniqueness
- c. Proximity
- d. Probability of Occurrence

C. Aesthetics

1. Plant Visibility

- a. Proximity to Communities
- b. Proximity to Frequently Traveled Roads
- c. Proximity to Recreation and Scenic Areas
- d. Topographic Influence

Source: Bechtel Power Corporation. Soda Springs Area Screen and Site Analysis. August 1977. Study conducted for Utan Power and Light Corporation.

Table IV-13

Estimated Coal Requirements for
Utah's Huntington and North Emery Powerplants

<u>Requirement</u>	<u>Huntington</u>		<u>North Emery</u>	
	<u>First Unit</u>	<u>First and Second Units</u>	<u>First Unit</u>	<u>First and Second Units</u>
Mw Capacity	415	815	415	830
Coal Required at Unit Rating	170 tons/hr	340 tons/hr	170 tons/hr	340 tons/hr
Coal Required at Average Annual Capacity Factor of 0.08	136 tons/hr	272 tons/hr	136 tons/hr	272 tons/hr
Yearly Coal Consumption	8000,000 to 1,200,000 tons	1,600,000 to 2,400,000 tons	800,000 to 1,200,000 tons	1,600,000 to 2,400,000 tons

Source: U. P. & L. Environmental Impact Statements, Huntington Canyon and North Emery Generating Stations.

gasification (different requirements for low, intermediate and high BTU gas processes), and (6) coal liquefaction.⁷

"Underground mining of coal requires little water. Surface mining, however, requires approximately 0.5 to 0.75 acre feet of water per acre of mined land, for dust control and rehabilitation. This water requirement may be higher in Utah, where mining takes place in areas having 10 inches or less of precipitation annually. Underground mining of coal usually produces water as a by-product. In this case, the problem is one of proper disposal of water because it frequently contains dissolved impurities."⁸ Water requirements of various coal technologies and of coal-fired electric generation are shown in Tables IV-14 and IV-15. The water requirements for proposed Utah electric generating stations are presented in Table IV-16. The average water requirement per megawatt of power is 16.54 acre feet with a standard deviation of 1.84 acre feet.

Air pollution requirements and waste disposal requirements are specifically outlined in Appendix A.

Table IV-14

COAL TECHNOLOGY WATER REQUIREMENTS

Technology	Water Requirements	
	Acre Feet Per 1000 Ton Coal	Gallons Per 1000 Ton Coal
Washing (estimates vary)	.016 to .06	5000 to 20,000
Gasification		
<u>Low BTU Gas</u> ^a	.05	15,223
<u>Intermediate BTU Gas</u> ^b		
Koppers-Totze Process	.13	43,803
Bureau of Mines Stirred Fixed Bed Process	3.8	1,230,000
<u>High BTU Gas</u> ^b		
Lurgi Process	2.3	762,712
Hygas Process	2.4	785,124
BI-Gas Process	5.9	1,908,163
Synthane Process	3.3	1,068,376
CO ₂ Acceptor Process	3.2	1,044,055
Liquefaction ^c	2.0	652,174

^a (11,770 BTU/lb. coal) in an Ash Agglomerating Fluidized Bed Process.

^b (8780 BTU/lb. coal)

^c This is net make-up water per 1000 ton coal per day. A typical 100,000 barrel per year liquefaction plant will require a total of about 20,000 AF of water per year, and 33,000 tons of coal per year.

Source: "Energy Alternatives: A Comparative Analysis", The Science and Public Policy Program, University of Oklahoma, May 1975.

Table IV-15

COAL AND WATER REQUIREMENTS FOR
COAL GASIFICATION PROCESSES^a
(High BTU Gas)

Process	Coal ^c	Water
Lurgi	16,577 tpd 6,050,605 ton/yr	18 x 10 ⁶ gpd 55.24 acft/day 20,164 acft/yr
Synthane	16,436 tpd 5,999,198 ton/yr	24 x 10 ⁶ gpd 76.73 acft/day 28,005 acft/yr
CO ₂ Acceptor	15,944 tpd 5,819,735 ton/yr	23.7 x 10 ⁶ gpd 72.74 acft/day 26,549 acft/yr
BI-Gas ^b	13,767 tpd 5,024,969 ton/yr	37.4 x 10 ⁶ gpd 114.78 acft/day 41,896 acft/yr
Hygas	16,998 tpd 6,204,299 ton/yr	19 x 10 ⁶ gpd 58.31 acft/day 21,284 acft/yr
^a 250 million cubic feet per day production. 91,250 million cubic feet per year production. ^b 950 BTU/cubic feet gas. ^c Utah coal with 12,500 BTU/lb. gpd = gallons per day tpd = tons per day acft = acre feet 325,829 gal = 1 acre feet		

Source: Wade V. Campbell and Rodney D. Millar, An Assessment of the Energy Resources in Utah: Part II Coal in Utah (office of State Science Advisor, Salt Lake City, Utah: 1978), p. 101.

Table IV-16

UTAH ELECTRIC GENERATING STATION WATER REQUIREMENT

Generating Station	Capacity (megawatts)	Water Requirements (acre feet)
Huntington (2nd Unit)	430	7,000
Emery (2 Units)	860	14,000
IPP	3,000	50,000
Garfield	2,000	30,000
Warner Valley	500	10,000
Alunite Plant	75	1,125
Total:	6,865	112,125

Source: Wade V. Campbell and Rodney D. Millar, An Assessment of the Energy Resources in Utah: Part II Coal in Utah (office of State Science Advisor, Salt Lake City, Utah: 1978), p. 102.

Potential Environmental and Socio-Economic Impacts*

Socio-economic impacts associated with power plant capacity expansions can be summarized in a variety of ways. For example, Gilmore, Moore and Hammond of the University of Denver Research Institute describe socio-economic impacts in terms of beneficiary--positive and victim--negative impacts.⁹ (See Table IV-17.) In a Massachusetts Institute of Technology study, Managing the Social and Economic Impacts of Energy Developments authored by Susskind and O'Hare, the socio-economic impacts are defined as the following: (1) social disruption, (2) public service needs, (3) shortage of private goods and services, (4) inflation, (5) public and revenue shortfalls, (6) resources lost to other uses, (7) aesthetic deterioration, and (8) fundamental community change.¹⁰ Chalmers and Anderson of Mountain West Research, Inc. categorize relevant socio-economic impacts as: (1) population, employment and income impacts, (2) community population impacts, (3) community facilities and services impacts, and (4) fiscal impacts.¹¹

As one examines the above lists of categorized socio-economic impacts, one observes that neither of these lists represents a complete presentation of the relevant socio-economic impacts associated with power capacity expansions.

*Material taken from Literature Search and Methodology Evaluation of Power Plant Siting Studies for Utah Great Basin Region conducted by this author.

Table IV-17

Social-Economic Beneficiary and Victim Impacts of Western Energy Development

Power Plant Developers and Labor Force of the Industry

Beneficiaries

- Plant owners
- Plant employees union vs. non-union
- Plant mgmt.
- Previously unemployed or underemployed Coloradoans now employed
- Previously unemployed or underemployed out of state

Victims

- Employees dissatisfied with quality of life (job, housing, etc.)
- Plant owners of non-profitable operations
- Co. employees who don't wish to relocate (co. could lose time/\$ training replacements)
- Employees at time of depletion or abandonment
- Industry over charged for community development costs

Suppliers and Customers of the Industry

Beneficiaries

- Refineries or downstream processors in NW Colo.
- Same, in rest of Colo.
- Same, outside of Colo.
- Final users of fuel, petrochemicals & synthetics from above
- Contractors
- Contractors' employees
- Equipment suppliers
- Material suppliers including electricity
- Unions
- Lenders to successful ventures
- Firms supplying new technology & scientific innovations necessary
- Firms using any "secondary" knowledge gained from technology used in oil shale development

Victims

- Employees dissatisfied with quality of life
- Contractors facing non-recoverable overruns from boom town upsets (oil co.'s will not be as sympathetic as utilities) or from plant/mine shutdown
- Displaced employees at time of mine depletion
- Lenders to unsuccessful ventures

Table IV-17 Con't

Competitors of the Industry		Government in Different Levels & Roles	
Beneficiaries	Victims	Beneficiaries	Victims
	<ul style="list-style-type: none"> *Producers of other fuels & other sources of hydrocarbon *Competitors in other synfuel industries seeking employees or customers *Producers of energy not equally subsidized (if synfuels subs. are granted) 	<ul style="list-style-type: none"> *Fed. gov't seeking domestic energy development *Fed. gov't with increased taxes & royalties, but little increase in demand for services *State & local gov't (community, school, & county) <u>if & when increased revenues exceed increased costs</u> *Local gov't entity enjoying windfall from jurisdictional mismatch *State & local gov't if given more power by Fed. legislation *Areas developed should become more important relative to other state areas & possibly state to other states lobbyists 	<ul style="list-style-type: none"> *Local gov't (community, school, & county) faced with increased costs & complexity & population fluctuations *State & local gov't until increased revenues exceed increased costs (level of services degraded) *Local gov't entities suffering from jurisdictional mismatches *State & local gov't if power is removed by Fed. legislation or regulations *Fed. or state gov't. <u>over</u> charged for community dev. costs

Table IV-17 Con't

Affected Bystanders

Beneficiaries

- Residents who eventually have tax rates lowered
- Residents who enjoy windfalls from jurisdictional mismatch
- Real estate speculators
- Mobile home dealers & landlords
- Successful local providers of goods & services

Victims

- Residents facing higher taxes & living costs without incremental income
- Residents facing reduced quality of life, including reduction of services by government entities
- Residents in area suffering from jurisdictional mismatch
- Businesses (including ranches) facing higher costs & greater competition for labor & resources
- Water users facing increased costs or reduced supplies or quality of water, e.g., ranchers, recreationists
- Second homeowners, recreationists & tourists
- Environmental activists
- Displaced political dominants & their reps.

Source: John S. Gilmore, Keith D. Moore and Diane M. Hammond, Working Paper #2, Synthesis and Evaluation of Initial Methodologies for Assessing Socioeconomic and Secondary Environmental Impacts of Western Energy Research Development (Denver: University of Denver Research Institute), p. 16.

Relevant Socio-Economic Impacts

As discussed earlier, no one author has developed an exhaustive list of the relevant socio-economic impacts of power capacity expansion. However, several studies have presented indepth discussions of one or more aspects of socio-economic impacts. Table IV-18 presents in outline form the most relevant socio-economic impacts. This outline represents a summary analysis of the various studies examined and are listed in the socio-economic bibliography in Appendix D.

Employment Impacts

The employment impact is one of the most primary-significant impacts. Most of the other socio-economic impacts such as population, housing, personal income, community facilities and services, community revenues, etc., are based on the outcome of the employment impact. The total employment impact includes the direct or basic employment associated with construction, operations, and maintenance employment and the indirect or nonbasic employment which relates to locally-oriented service activities or those employment activities which meet the demands of various goods and services for the impacted compacted communities.¹² Given the nature of the power capacity expansion project (coal mining, power plant, limestone quarry, transmission lines, coal slurry pipeline, railroad, and/or additional roads), the direct or basic employment impact consists of a forecast, generally provided by the corporations involved in the construction, operations, and maintenance phases of the above operations.

The indirect employment impact consists of evaluating the number of jobs and type of jobs required to support the direct or basic labor force. This indirect employment impact is one of the most basic, yet

Table IV-18

Relevant Social-Economic Impacts
of Power Capacity Expansions

I. Employment, Population, Households, and Personal and Corporate Income Impacts.

A. Employment.

1. Total Direct and Indirect Construction Employment Over Construction Time Period by Age and Sex.
2. Total Direct and Indirect Operations Employment Over Operations Time Period by Age and Sex.
3. Distribution of Indirect Employment by Employment Sector by Age and Sex.
4. Importation of Labor.
5. Forecast of Labor Force Participation Rates by Age and Sex.
6. Forecast of Unemployment Rate by Industry Sector.
7. Forecast of Rate Working Wives in the Labor Force and Household Size Where the Wife Works.
8. Multiple Job Holding Rate Per Individual Employee.

B. Population Over Construction and Plant Operation Time Periods by:

1. Age, Sex, and Special Sub Populations.
2. Geographic Allocation of Population to Surrounding Communities and/or New Towns.
3. Projection of School Age Population and Geographic Distribution.

C. Households.

1. Number of Direct, Indirect, and Households Which Have Both a Direct and Indirect Employees Residing in Them.
2. Geographic Allocation of Households to Surrounding Communities and/or New Towns.
3. Type of Housing Needed.
 - *Rental
 - *Owner
 - *Mobile Home
 - *Apartment
 - *Condominium
 - *Single Family Dwelling

D. Personal Income.

1. Salaries and Wages of Direct and Indirect Employees.
2. Proprietor's Income.
3. Dividends, Interest and Rent.
4. Personal Contributions for Social Insurance.
5. Transfer Payments.
6. Other Income.
7. Unemployment Benefits.
8. Residency Adjustment.

II. Social-Community Population Impacts.

- A. Community Allocation of Non-Local Construction and Operations Employees (Including Population, Households and Income).
- B. Community Reallocation of Local Construction and Operations Employees (Including Population, Households and Income).
- C. Land-Owner Dislocations Geographic.
- D. Property-Land Value Changes Geographic.
- E. Community Attitudes and Public Acceptance of the Proposed Power Capacity Expansion.
- F. Social Disruption.
 - 1. Alcoholism.
 - 2. Drug Abuse.
 - 3. Mental Illness.
 - 4. Divorce.
 - 5. Juvenile Delinquency.
 - 6. High Worker Turnover.
 - 7. Low Worker Productivity.
- G. Fundamental Community Change.

III. Community Facilities and Services Impacts (Including Capital Costs, Operation and Maintenance Costs, and Growth Management Costs).

- A. Water Supply.
- B. Waste Water Treatment.
- C. Solid Waste Disposal.
- D. Power and Light.
- E. Communications.
- F. Roads (Including Major Access Highways).
- G. Police Protection.
- H. Fire Protection.
- I. Health Care.
- J. Social Welfare Assistance.
- K. Parks and Recreation.
- L. Libraries.
- M. Education--Schools.
- N. Mass Transportation.
- O. General Administration and Control.
- P. Airport(s).
- Q. Planning and Zoning.
- R. Justice System.

IV. Public Revenues.

- A. Local.
 - 1. Sales and Use Tax.
 - *Mine Materials
 - *Slurry Pipeline and/or Railroad Materials
 - *New Town Materials
 - *Plant Materials
 - *Other Community Materials
 - 2. Retail Sales Tax.
 - *New Town
 - *Other Impacted Communities-Utah/Idaho
 - 3. Property Tax.
 - *Plant
 - *Mine
 - *Quarry

Table IV-18 Con't

- *Slurry Pipeline and/or Railroad
- *Commercial--Utah/Idaho
- *Personal
 - New Town
 - Other Impacted Communities--Utah/Idaho
- 4. Operation Licenses and Permits.
- 5. Other Miscellaneous Revenues (i.e., Excess and Franchise Taxes).
 - *General Administration
 - *Planning and Zoning
 - *Airport
 - *Public Buildings
 - *Employee's Retirement
- 6. Government Expenditures-Local and County.
 - *General Administration
 - *Streets and Highways
 - *Public Safety
 - *Justice Expenditures
 - *Planning and Zoning
 - *Health and Hospitals
 - *Airport
 - *Public Welfare
 - *Parks and Recreation
 - *Public Buildings
 - *Employees Retirement and Social Security
 - *Miscellaneous and Unclassified Expenditures
 - *Capital Outlay
 - *Utility Expenditures
 - *Outstanding Debt
- 7. Government Revenues-Local and County.
 - *Property Taxes
 - *Specific Ownership Taxes-Vehicles, Etc.
 - *Excise and Franchise Taxes
 - *Licenses and Permits
 - *Fees, Fines and Forfeits
 - *Revenues from Other Governments
 - *Miscellaneous Revenues
 - *Sales Tax
 - *Motor Fuel Tax
- 8. Land Use.
 - *Agriculture and Urban
 - *Mineral Resources
 - *Recreation Land
 - *Transportation
 - *Constraints on Development
- 8. State.
 - 1. Sales and Use Tax.
 - *Mine-Materials
 - *Plant Materials
 - *Slurry Pipeline Materials and/or Railroad Materials
 - *New Town Construction Materials
 - *Other Community Materials
 - 2. Retail Sales Tax.
 - *New Town
 - *Other Impacted Communities--Utah/Idaho
 - 3. Personal Income Tax.
 - 4. Corporate Franchise Tax.

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- 5. Share of Coal Royalty.
- 6. Share of Coal Lease.
- C. Federal.
 - 1. Personal Income Tax.
 - 2. Corporate Income Tax.
 - 3. Share of Coal Royalty.
 - 4. Share of Coal Lease.
- V. Government Revenue Shortfalls.
 - A. Local Communities (Including New Town).
 - B. Counties.
 - C. States.
 - D. Federal.
- VI. Shortage of Private Goods and Services.
 - A. Housing.
 - B. Wholesale, Retail and Service Sectors Goods and Services.
- VII. Inflation (Excess Demand Triggers Inflation in Prices, Wages and Rents).
 - A. Impact on Senior Citizens and Others Who Are on Fixed Incomes Who Cannot Take Advantage of Higher Wages.
 - B. High Construction Wages Combined With A General Labor Shortage Will Cause Wages in Other Economic Sectors to Increase. (This Can Hurt Agricultural Economy Though Agricultural Workers Benefit From Higher Wages If Their Employers Do Not Go Out of Business.)
- VIII. Resources Lost to Other Uses.
 - A. Water, Land and Labor. (Industry and Its Workers Are Notably Consumptive of Three Resources Needed by the Agricultural Economy.)
 - B. Capital.
 - C. Loss of Agricultural Productivity.
 - 1. Soil.
 - 2. Climate.
 - 3. Present Cultivation Practices.
 - 4. Present Type and Quantity of Production.
 - 5. Irrigation Use.
 - 6. Farmsteads Dislocated.
 - 7. Future Changes in Regional Productivity.
- IX. Aesthetic Deterioration.
 - A. Power Capacity Expansion Visibility.
 - B. Power Capacity Expansion Proximity to Local Communities.
 - C. Power Capacity Expansion Proximity to Frequently Traveled Roads.
 - D. Power Capacity Expansion Proximity to Recreation and Scenic Areas.
 - E. Topographical Influence.

Sources: This table was derived from the Socio-economic Bibliography (See Appendix E).

critical impact of the socio-economic impacts. Several methodologies have been used in forecasting this labor impact.¹³

The most common methodology found in the literature search was the employment multiplier. Specific aspects of the indirect employment impact include the following: (1) forecast of supply and demand including forecasts of labor force participation rates by age and sex and forecast unemployment rates for the major industry sectors, (2) estimates of the rate of multiple job holding per employee, (3) rate at which both spouses in a given household are employed in direct and/or indirect jobs, and (4) allocation of labor force to the existing communities and/or new towns in the power capacity expansion area.

Population Impacts

Population impact consists of determining the total population by age and sex based on the direct construction, operations, maintenance employment and also for the indirect employment which supports or provides goods and services for the direct or basic employment group. Special subpopulations often compose one or more segments of both the direct and indirect employment groups and often exhibit significantly different population characteristics (fertility, death and marriage rates, etc.); therefore, these special subpopulations should be isolated and handled as a separate group in terms of evaluating the impact on total population and also the age and sex distribution. Two specific aspects of the population are geographic allocation of the population to the surrounding communities and/or new towns with special emphasis and the unique subpopulation groups.

The Handbook for Environmental Planning suggests that short distance migration is a function of the following independent variables: (1) quality of schools, (2) appearance-quality of available housing, (3)

size of house, (4) cost of the house, (5) scenic qualities of the neighborhood in which there exists housing availability, (6) property tax rates, (7) proximity to schools, churches, and other community facilities, (8) prestige of the neighborhood, (9) accessibility to major roads and highways, (10) availability and cost of sewage, water and other utility facilities, (11) socio-cultural factors and (12) shopping facilities.¹⁴

Households and Housing Impacts

The total number of households is derived from the employment and population impacts. Any given household may be comprised of a direct employee, an indirect employee, and more than one direct employee and/or indirect employee. Call Engineering¹⁵ and Bateman and Wistisen¹⁶ have specifically examined this employment to household allocation process.

In addition to the above authors, Chalmers and Anderson¹⁷ have developed models for the geographic allocation of these households to existing communities and/or new towns. This impact is significant in terms of determining the demand for housing by type and location of the imported labor. For example, in the past a large percentage of the construction employees have traveled from one job location to another and have generally resided in mobile homes, but yet have demanded the same types of goods and services as other employees. Specific factors associated with geographic allocation of households includes: (1) dwelling types, availability, quality and cost, (2) aesthetic and health amenities--park facilities and open space areas, (3) socio-cultural factors--community integration and solidarity, access to and quality of schools, access to commonly used shopping facilities and entertainment

facilities, and overall quality and availability of other community services and facilities.¹⁸

Personal and Corporate Income Impacts

The personal income impact includes both the magnitude of personal income and the geographic distribution of personal income. The categories of personal income relevant to the power capacity expansion impacts include: (1) salaries and wages of direct and indirect employees, (2) proprietor's income, (3) dividends, interest and rent, (4) personal contribution for social insurance, (5) transfer payments, (6) residency adjustment, (7) unemployment benefits, and (8) other personal income. Corporate income impact also requires the magnitude and geographic distribution of business--corporate profits. These profits include the corporate business profits from the power plant, coal mine, limestone quarry, transmission lines, coal slurry pipeline, railroad, or trucking operations, etc., which are directly related to the power capacity expansion project and corporate--business profits from the secondary support sector (e.g., profits from the additional restaurants, recreation facilities, etc., which are required to support the direct or basic population group).

Social Community Impacts

This section primarily identifies the social and economic impact of a power capacity expansion project for the existing communities and also for the new towns which might be required to support the growth in population. The social community impacts examine the sudden changes in population mix and patterns of everyday life.¹⁹ Gilmore in his study of the social problems in Rock Springs which resulted from energy development concludes that these social problems can be described as a problem triangle or a vicious circle which results from a large influx

of workers. This problem triangle has the following parts: (1) local institutions and markets respond slowly to increased demand, (2) the imbalance between supply and demand degrades the quality of life, and (3) workers in all industries are less productive and are more prone to absenteeism, which in turn slows down the response of local institutions to the influx of workers.²⁰ Specifically, the social community impacts include: (1) community attitudes and public acceptance of the proposed power capacity expansion, (2) social community disruptions (increased rates of alcoholism, drug abuse, mental illness, divorce, and juvenile delinquency, higher rates of worker turnover, lower rates of worker productivity, etc.), and (3) geographic dislocations of land owners resulting from the proposed expansion (generally longtime community residents suffer more than newcomers).²¹ Another social community impact is labeled by Susskind and O'Hare as "fundamental community change."²² This impact is the change that occurs to the original residents of the community who have chosen to remain because they viewed their place of residence and community as the best place for them. The fundamental change occurs when the appearance, social structure, friendship patterns, style of life, and almost everything else changes, and the community that supported this group of people simply disappears.

The community impact examines the geographic distribution of changes in property values from the power capacity expansion project.

Community Facilities and Services Impacts

The impact measures the capital costs, operation costs, maintenance costs, and growth management costs. Included in the measurement of these costs are the personnel and management requirements which will be required to operate the new and expanded facilities. In addition, this impact evaluates the changes in carrying capacity of the community

facilities: zoning ordinances, land use patterns, water, sewer, etc. The community facilities and services evaluated in this impact analysis include: water supply systems, waste water treatment plants, solid waste disposal plants, power and light facilities, communications (radio, television, etc.), roads (including major access highways), police protection, health care facilities, social welfare assistance, justice systems, parks and recreation facilities, libraries, mass transportation facilities, airports, and general administrative government and control including planning and zoning administration and control. Primarily, this group of community measures the various levels of government expenditures which are required to provide and maintain adequate levels of public infrastructure.

Public Revenues Impacts

The impact of public revenues are distributed by the level of government: local governments, state governments and the federal government. Local government revenues include sales and use tax, retail sales tax, property tax, operating licenses and permits, and other miscellaneous revenues. The state portion of public revenues impact also includes sales and use tax and retail sales tax in addition to personal income tax, corporate franchise tax and the state's share of coal royalties and coal leases. The federal government revenues impacts includes the determination of personal income tax, corporate income tax, and the federal government share of coal royalties and coal leases.

Government Revenues Shortfall Impacts

The government revenue shortfalls measures the public costs burden by level of government--local, county, state and federal of the power capacity expansion. This impact attempts to measure the relative

difference over time between the public revenues and the community facilities and services expenditures.

Shortage of Private Goods and Services Impacts

This socio-economic impact specifically examines over the construction period and operations period of the power capacity expansion the shortage of housing, wholesale, retail and service sector goods and services.

Inflation Impacts

The inflation impact is characterized by excess demand which hereby triggers the rate of inflation for various goods and services, wages and rents. Two specific impacts should be considered. First, the impact of inflation on senior citizens and other citizens who are living on fixed incomes who are not able to take advantage of higher wages resulting from the power capacity expansion projects. The second major inflation impact is illustrated by the high wages paid to construction employees combined with a general labor shortage. This situation generally causes wages in other economic sectors to increase. This situation can injure the agricultural economy even though the agricultural workers will benefit from higher wages, if the farmers do not go out of business.

Resources Lost to Other Uses Impacts

This impact is relatively difficult to evaluate. However, the optimum employment or utilization of various economic goods and services should be examined in terms of the relative opportunity costs associated with land, labor, capital, and water resources. Also, the loss of agricultural productivity should be specifically examined.

Aesthetic Deterioration Impacts

The impact of aesthetic deterioration generally includes such

issues as visibility, proximity to local communities, proximity to frequently traveled roads, and proximity to recreation and scenic areas of the power capacity expansion projects.

Transportation Tradeoffs

Coal transportation in the western states depends largely on railroads and trucks. "Railroad transportation of coal is oftentimes beset by slow transit and turn around times, poor truck conditions, the lack of suitable equipment, unduly restrictive labor practices, financing and rate problems. Coal slurry pipelines have a definite role in the long-distance transportation of large volumes of western coal."²³

Some railroad capacity limitations that are not directly related to the financial well being or the ability to borrow by the railroad company are summarized by the U.S. Department of Energy. These limitations include:

- (1) Inadequate sidings and passing trucks.
- (2) Local ordinances mandating low speed limits within cities and towns.
- (3) Time delays placing corrective improvements in place.
- (4) Lack of opportunity by states, counties and towns to acquire revenues based on increased coal hauling.
- (5) Possible creation of safety districts that could hinder rather than aid quick passage of all trains.
- (6) Failure to take remedial action on by-pass routes where existing routes have been closely surrounded by residential development.²⁴

Most of Utah's coal will be removed by other means rather than by Utah's highway network. (See Figure IV-6.) Moreover, the development of a highway-coal transportation network is extremely costly--approximately \$200,000 to \$500,000 per mile²⁵ for highway improvement and \$1.2 million to \$1.5 million per mile for the construction of a new highway. In

Figure IV-6

Source: Utah Department of Transportation and Federal Railroad Administration; Utah's Unit Coal Trains: Today and Tomorrow, February 1980, p.7

comparison, the cost to construct a coal slurry pipeline ranges from \$300,000 to \$500,000 per mile.²⁶

The National Electric Reliability Council summarizes the situation of the development of coal slurry pipelines in the following:

Coal slurry pipelines have a definite role in the long distance transportation of large volumes of western coal to locations such as the southwestern area of the country, an area heavily committed to future coal-burning plants. The only coal pipeline now in service is in the western United States. Others cannot be built unless Congress grants powers of eminent domain to pipeline contractors. Opposition to slurry pipelines currently comes from railroads and environmentalists who oppose such legislation. Even though such legislation is passed, lengthy litigation seems inevitable.²⁷

Other issues relative to the transportation tradeoff analysis include the generation of electrical power at the source of the coal reserve with the electricity transmission by high voltage lines vis-a-vis coal slurry pipeline and transportation of the conversion of coal to a liquid or gas capable of being used in conventional transportation systems and existing combustion devices.

Footnotes-Section IV

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⁶Ibid., pp. 9298.

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⁸Ibid., p. 99.

⁹John S. Gilmore, Keith D. Moore, and Diane M. Hammond, Working Paper #2, Synthesis and Evaluation of Initial Methodologies for Assessing Socioeconomic and Secondary Environmental Impacts of Western Energy Research Development (Denver: University of Denver Research Institute).

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¹¹J. A. Chalmers and E. D. Anderson, Economic/Demographic Assessment Manual, Current Practices, Procedural, Recommendations, and a Test Case (Tempe, Arizona: Mountain West Research, Inc.), pp. 34.

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¹³Susskind, Managing Social and Economic Impacts of Energy Development, p. 8.

¹⁴James McEnvoy III and Thomas Dietz, Ed., Handbook for Environmental Planning, The Social Consequences of Environmental Change (New York: John Wiley & Sons, 1977), p.

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¹⁸James McEnvoy III and Thomas Dietz, Eds., Handbook for Environmental Planning, The Social Consequences of Environmental Change.

¹⁹Susskind, Managing Social and Economic Impacts of Energy Development, p. 8.

²⁰John S. Gilmore, "Boom Towns May Hinder Energy Resource Development," Science 191, February 1976, p. 536.

²¹Susskind, Managing Social and Economic Impacts of Energy Development p. 8.

²¹Susskind, Managing Social and Economic Impacts of Energy Development, p. 8.

²²Ibid., p. 9.

²³National Electric Reliability Council, Fossil and Nuclear Fuel for Electric Utility Generation Requirements and Constraints, 1977-1986 (National Electric Reliability Council: August 1977), p. 5.

²⁴U.S. Department of Energy, Interregional Coal Transportation Task Force, Moving a National Resource: A Compendium On Interregional Coal Transportation (U.S. Department of Energy: September 1978), pp. 4-3 and 4-4.

²⁵Ibid., p. 4-9

²⁶Martin J. Wistisen, Evaluation of the Public Cost Burden of Alternative Uses of Kaiparowits Coal in Kane County, Utah (Office of Minerals Policy Development, U.S. Department of Interior, Washington, D.C.: February 1977), pp. 4 and 5.

²⁷Op. Cite., National Electric Reliability Council, p. 5.

SECTION V

URANIUM RESOURCES IN UTAH

Utah uranium resources are estimated to be approximately 16.3 million tons. As of January 1979, total tons of uranium ore in the U.S. is 1,300 million tons (at \$50 per pound recoverable cost). Utah's uranium resource represents 1.3 percent of the total U.S. reserve. (See Table V-1.) As shown in Figure V-1, almost all of the U.S. uranium resource is found in Western States.

Resource Potential and Location

Utah's potential uranium resource is scattered in the southeastern counties, specifically in San Juan, Emery, Garfield, Grand, and Wayne Counties. However, Beaver, Piute and Washington Counties have some uranium reserves. Of Utah's 16.3 million tons there is currently no firm estimate of Utah's recoverable uranium reserves.¹ Approximately 53 percent or 18.7 million tons of Utah's gross reserve has been recovered for production of U_3O_8 . The production of uranium in Utah by county is shown in Table V-2.

Resource Technology, Development, and Production Status

Nuclear energy is expected to show the largest relative increase of all sources of generation to electric energy production in the United States.² The use of nuclear fuels differ from fossil fuels in the following ways:

Table V-1

Potential Uranium (U_3O_8) Resources
In The Western United States¹

(January 1, 1979)

State	Tons of Ore (Millions)	Grade % U_3O_8	Tons of U_3O_8	Percent of Total Tons U_3O_8
New Mexico	539	0.09%	447,000	52%
Wyoming	504	0.06%	287,000	31%
Texas	97	0.05%	50,000	5%
Arizona, Colorado and Utah	123	0.07%	83,000	9%
Others: Alaska, California, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Washington	<u>37</u>	<u>0.07%</u>	<u>26,000</u>	<u>3%</u>
TOTALS	1,300	0.07%	920,000	100%

¹These estimates include uranium recoverable (\$50 per pound) by solution mining.

Source: Utah State Energy Office, Utah Energy Sourcebook, p.5

Figure V-1

SIGNIFICANT URANIUM AREAS OF THE UNITED STATES

Table V-2
Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Beaver	Babbitte, Grebe, Henderson & Chastain	Fortuna Mine	No Production
	Gold Silver Exploration	Sheep Rock Mine	No Production
	La Var Hollingshead Hollingshead Mining & Milling	Holly Mine, Blond Mountain Area	1-100
Emery	Donald Acerson or Alfred O. Acerson	Darlene, Come-to-ite, San Rafael River Mining Area, Green River Desert Mining District	No Production
	Accosciated Energy Corp.	Cistern, San Rafael Swell	No Production
	Atlas Minerals	Incline, San Rafael River Mining Area, Green River Desert Mining District	No Production
	Atlas Minerals	Incline, Four Corners Mine, Snow Mine, San Rafael River Mining Area, Green River Desert Uranium District	1,000-100,000
	Atlas Minerals Division of Atlas Corp.	San Rafael River Mining Area, Green River Desert Mining District	No Production
	Atlas Minerals Division of Atlas Corp.	Probe Mine, San Rafael River Mining Area	No Production
	Atlas Minerals Division of Atlas Corp.	Red, San Rafael River Mining Area, Green River Desert Uranium District	No Production
	Atlas Minerals Division of Atlas Corp.	Wedding Bell, San Rafael River Mining Area	No Production
	Big Rock Mining Co.	Gamma Incline, Ridge Group, Mac, Green River Desert Mining District Green River Uranium District	100-1,000
	Birch Mining Co.	San Rafael River Mining Area, Green River Desert Mining District	1,000-100,000
	Central Oil & Mining Corp.	Delta Group, San Rafael Swell	No Production
	Chinook Construction & Engineering Limited	Wayne Smith Fee Mine, Aud Mine, Green River Uranium District	100-100,000

Table V-2 Con't

Uranium Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Emery (cont.)	Cimmeron Mining Inc.	Spanish Trail Mine, San Rafael Mining District	100-1,000
	Cleghorn & Washburn	Snow Shaft, Jack Rabbit Mines, and Others, San Rafael River Mining Area, Green River Desert Mining District	1,000-100,000
	Leo J. Cline	Vanadium King Mine, Temple Mountain San Rafael Mining District, San Rafael Uranium District	No Production
	Don Curtis	Gamma Mine	1-100
	Dum Jac Mining Co.	Mac Mine, San Rafael Mining District	100-1,000
	Darys Ekker	Yellowsands Mine	1-100
	Hannert Mining Inc.	Lucky Strike, San Rafael Swell	1,000-100,000
	Doran Hunt Mining Co.	Delta Mine, San Rafael Swell	No Production
	Kay Hunt	Bluebird Mine, Southern San Rafael Swell	No Production
	Industrial Nuclear Co.	Dirty Devil, Temple Mountain Area	1,000-100,000
	Jensen & Korris	North Slopes, San Rafael River Mining Area, Green River Uranium District	No Production
	John Johnson	Sundown	100-1,000
		Merdy Cat, Temple Mountain Area	100-1,000
	Marathon Oil Co.	Sinbad Project, San Rafael Swell	Data Withheld
	Mineral Investments Inc.	Flat Top, San Rafael Swell	No Production
		Red Chip Mine, Coal Cliffs Area	No Production
	Minex Corporation	Eagle Mine, Coal Cliffs Area, East of Emery	No Production
	Nolan and Harlod Olsen, Trusts, Adams Mining Co.	Dexter Mine, San Rafael Swell, Calf Mesa Mining District	100-1,000
	Alan S. Pike	Copper Globe, San Rafael Swell	No Production
	Powell Mining Co.	Drill & Butch, Green River Mining District	No Production

Table V-2 Con't

Uranium Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Emery (cont.)	A. L. and Elmer L. Sherman	Hilltop Mine, San Rafael Swell	No Production
	Michael J. Skopos	Flat Top Mine, Temple Mountain Area	No Production
	Temple Rock Mining	Vanadium King Mine	1,000-100,000
	Trio Industries, Inc.	Sahara Mine, Green River Desert Mining District	100-1,000
	Utah West Mining & Development	Delta Mine, San Rafael Swell	No Production
	Watterson Mining Co.	Blue Pick Mine	100-1,000
		Dime Mine	1,000-100,000
		Drill Mine	100-1,000
		Desert Moon	100-1,000
		San Rafael Swell Region	
	Bert L. Wilcox	Birthday Mine, San Rafael River Mining Area, Green River Desert Uranium District	No Production
Garfield	Paul B. Alexander	New Mockingbird Mine, Henry Mountains Uranium District	100-1,000
	Associated Energy Corp.	Blitz, Knob, Tracheyte, School Section, Henry Mountains Uranium District	100-1,000
	Colt Mesa Mining Co.	Horsehead, Henry Mountains Uranium District	No Production
	Dawson Mining Co.	Cedar Point, Gateway Uranium District	No Production
	Dennis Ekker	Del Monte, Congress, Tacheyte Mines Henry Mountains Uranium District	100-1,000
	Jesse Ekker	Farah Fay Mine, Henry Mountains Uranium District	100-1,000
	Kerry B. Ekker	Mcdock Mine, Henry Mountains Uranium District	1-100
	Teddy C. Ekker	Daisy June Mine, Henry Mountains Uranium District	100-1,000

Table V-2 Con't
Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Garfield (cont.)	Footo Mineral Co.	Henry Mountain Group, Henry Mountain Uranium District	No Production
	C. Alfred Frost	Yellow Queen, Henry Mountains Uranium District	1-100
	H. L. Harper	Straight Creek, Henry Mountains Uranium District	100-1,000
	Hope Mining Co.	Hope Mine, Henry Mountain Uranium District	No Production
	Willard C. Haight	Congress-Delmonte, Minnie Pearl, Henry Mountains Uranium District	No Production
	Hunt Mining Co.	Minnie Pearl Congress, Daisy June, Trackyte Properties, Delmonte, Eagle, John Hill Flat, Juen Bell, Henry Mountains Uranium District	No Production
	Hunt Mining Co.	Straight Creek, Henry Mountains Uranium District	100-1,000
	Hunts Service	Tracheyte Mine, Henry Mountains Uranium District	100-1,000
	Hunts Uranium Co.	Poison Spring, Henry Mountains Uranium District	1-100
	Hydro-Jet Services Inc.	Ace, Copper Creek, Trail Canyon, Rats Nest, Buckeye, Yellow Paint, Jets, Henry Mountains Uranium District	Data Withheld
	John Johnson	Tammy, Henry Mountains Uranium District	100-1,000
	Kachina Mining & Construction Co.	Tracheyte, Henry Mountains Uranium District	1,000-100,000
	Richard D. Kipp	Sandy Mine, Henry Mountains Uranium District	100-1,000
	Ronald E. Martin, August Priebe Jr., and D. D. Hanni	Yellow Queen Mine, Henry Mountains Uranium District	1,000-100,000

Table V-2 Con't

Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Garfield (cont.)	Minerals Recovery Corp.	Farmers Knob, Notom, Eagle, School Section, Trachyte Circle Cliffs, Horsehead, Henry Mountains Uranium District	No Production
	Charles W. Noyes & Sons	Ardell, Henry Mountains Uranium District	1-100
	P & P Associates	Shitamaring, North Wash, Henry Mountains Uranium District	No Production
	Plateau Resources, Ltd.	Tony "M" Mine, Lucky Strike Mine, Little Rockies Area, Henry Mountains Uranium District	1,000-100,000
	John Dee Raey	Donald Duck Mine, Henry Mountains Uranium District	1-100
	Shelco, Inc.	SL, Shelco Mine, Henry Mountains Uranium District	100-1,000
	Shooter Creek, Mining Corp.	Agate Mine, Little Rockies, Henry Mountains Uranium District	No Production
	S.B. Stevens & Co.	Valear Mine, Trachyte Wash, Henry Mountains Uranium District	No Production
	Urango Mining Co.	North Wash Mine, Henry Mountains Uranium District	1,000-100,000
	Vanadium Corp. of America	John Hill Flat Mine, Trachyte Wash, Henry Mountains Uranium District	Data Withheld
Grand	Lewis R. Wilcox	Tammy Tracheyte, Henry Mountains Uranium District	1-100 1-100
	Worldwide Energy Corp.	Last Chance, Henry Mountains Uranium District	No Production
	Airborne Prospectors, Robert Shumway	Almost Mine, Inter-river, Little Grand Mining District, Green River Uranium District	No Production
	Atlas Minerals, Division of Atlas Corp.	Cactus Rat Mine, Yellow Cat Mining District, Thompson Uranium District	No Production

Table V-2 Con't

Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Grand (cont.)	Atlas Minerals, Division of Atlas Corp.	Cane Creek Mine SL State	No Production 100-1,000
	Atlas Minerals, Division of Atlas Corp.	Ringtail, State Survey, Thompson Uranium District	No Production
	H. W. Balsley	Emma, Lillie, Katie Mines, La Sal Mining District	No Production
	Butt Mining Co.	School Section, Green River Uranium District	No Production
	Buttes Gas & Oil Co.	10 Mile, Spanish Castle, Green River Uranium District	No Production
	Continental Nuclear Corp.	Black Jack, Thompson Uranium District	No Production
	Cordero Mining Co.	Sure Pay, Pond, Shubert Mines, Moab Region	No Production
	Homer E. Davis	Blackstone Mine, Thompson Uranium District	No Production
	Dawson Mining Co.	Rae Marie, Green River Uranium District	No Production
	Durfee Mining Co.	John, Thompson Uranium District	No Production
	General Electric Uranium Management Corp.	Seven Mile Mine, Moab Uranium District	1,000-100,000
	Harrison Mining Co.	Shinarump, Inter-river, Seven Mile Uranium District	No Production
	D. Kelly and A. Pene	Little Eva, Thompson Uranium District	No Production
	Lammert Mining Co., James R. Lammert, and Bill Burgess	SL Frantion, Inter-river, Little Grand Mining District, Green River Uranium District	1,000-100,000 1-100
	Loretto Mining Co.	Loretto Properties, Green River Uranium District	No Production

Table V-2 Con't

Uranium Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Grand (cont.)	Lee H. Morris	Desert Rat-Badger Mine, Sunday, M & M Mines, Green River Uranium District	1-100
	Power Oil Co., General Electric Nuclear Energy Division	Copper King, South Fork, Green Dragon, Moe, Protection, Star, Lyon, Seven Mile Canyon, Little Grand Mining District, Green River Uranium District	No Production
	A. D. Rice	Toby Mine, Thompson Uranium District	No Production
	Robert & Donald Rowe	Black Ape Mine, Yellow Cat Mining District	1-100
	D. Howard Shields	Lena Mine, Courthouse Wash, Little Grand Mining District, Thompson Uranium District	No Production
	Shiprock Ltd.	Corvusite Mine, Beaver Mesa, Polar Mesa Mining District, Thompson Uranium District	No Production
	Jerry Stocks Mining Co. Continental Nuclear Corp.	Black Jack, Thompson Uranium District	No Production
	Terra Marine Mining Co. Cotter Corp.	Black Ape Mine, Thornburg Memorial Mine, Bicentennial Mine, Seven Mile Canyon, Little Grand Mining District, Green River Uranium District	100-1,000
	Union Carbide Mining & Metals	First Chance Mine, Yellow Cat Mining District, Thompson Uranium District	1,000-100,000
	Union Carbide & Carbon Corp.	F. W., Polar Mesa Mining District, Gateway Uranium District	1,000-100,000
	URANIUM, VANADIUM		
	Amax Uranium Co.	Cane Creek School, Cane Canyon, Moab Uranium District	No Production
	Amax Uranium Co.	La Sal Group, Gateway, Polar Mesa Mining District, Gateway Uranium District	No Product

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Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Grand (cont.)	Atlas Minerals, Division of Atlas Corp.	Utex Dump	No Production
	Shiprock Ltd.	Cedar Point Mine, Beaver Mesa, Polar Mesa Mining District, Gateway Uranium District	No Production
	Shiprock Ltd.	Rae Marie Mine, Beaver Mesa, Polar Mesa Mining District, Gateway Uranium District	No Production
	United Energy Co.	Agate Mine	1-100
	Union Carbide & Carbon Corp.	Polar King, Elva, Effie Mines Gateway Uranium District	1,000-100,000
	Union Carbide & Carbon Corp.	Red Vanadium Mine, Yellow Cat Mining District, Thompson Uranium District	1,000-100,000
	Uranium Production Co.	Almost Mine	1,000-100,000
	Utah Alloy Ores Inc.	Allor, Little Pittsburgh, Yellow Cat Mining District, Thompson Uranium District	No Production
Piute	Utah Alloy Ores Inc.	Parco, Telluride Mine, Yellow Cat Mining District, Thompson Uranium District	No Production
	Annie Laurie Mining Ventures Ltd.	Mill Site, Tip Top, Olive Pit, Grasshopper Pit, Marysvale Mining District	No Production
	Arundel Mining Co.	Marysvale Properties, Marysvale	No Production
	Atlas Minerals, Division of Atlas Corp.	Marysvale Group, Marysvale Mining District	No Production
	Minex Inc.	Farmer John Properties, East of Marysvale, Marysvale Mining District	No Production
	Petro Nuclear Ltd.	Freedom Mine Properties, East of Marysvale, Marysvale Mining District	No Production

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Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
Piute (cont.)	Pratt Seegmiller	Freedom Mine, Marysvale Mining District, Salt Lake Uranium District	1-100
	Snyder, Kennedy & Smith	Propector Mine, Marysvale Mining District, Salt Lake Uranium District	100-1,000
	Standard Gold & Silver Inc.	South Fork Mine, Marysvale Mining District	No Production
	Vanadium Corp. of America	Vanadium Corp., Marysvale Mining District, Salt Lake Uranium District	Data Withheld
	Western Nuclear Inc.	Sugar Daddy, Marysvale Mining District	No Production
San Juan	Allied Mission Oil Inc.	Vanadium Queen, La Sal District, Paradox Valley Mining District	100-1,000
	Atlas Minerals	Ale-Ale Fraction, Lisbon Valley, Big Indian Mining District, Monticello Uranium District	No Production
	Atlas Minerals	Ann Mine, Lisbon Valley, Big Indian Mining District, Monticello Uranium District	No Production
	Atlas Minerals	Atlas, MiVida, TeQuiero, Lisbon Valley, Big Indian Mining District, Monticello Uranium District	No Production
	Atlas Minerals	Bacardi, D & D	No Production
	Atlas Minerals	Bardon Mine, Big Indian Mining District	No Production
	Atlas Minerals	Big Buck, Southwest Lisbon Valley, Big Indian Mining District	No Production
	Atlas Minerals	Blue Goose, Blue Jay, Snowflake, Sunflower, Sunnyside, and Prince Albert Mines, Big Indian Mining District, Moab Uranium District	No Production

Table V-2 Con't

Uranium Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Atlas Minerals	Brechtel-Louise Mine, Lisbon Valley, Big Indian Mining District, Monticello Uranium District	No Production
	Atlas Minerals	Calliham, Sage Mine, Monticello Uranium District	1,000-100,000
	Atlas Minerals	Columbia, Patti-Ann, Big Indian Mining District	1,000-100,00
	Atlas Minerals	Dunn Mine, Monticello Uranium District	No Production
	Atlas Minerals	Expectation-Stinko, Big Indian Mining District, Monticello Uranium District	No Production
	Atlas Minerals	Far West Incline, Southwest Lisbon Valley, Big Indian Mining District	1,000-100,000
	Atlas Minerals	Ford Mine, Southwest Lisbon Valley, Big Indian Mining District	No Production
	Atlas Minerals	Happy Jack Mine, White Canyon Mining District, White Canyon Uranium District	1,000-100,000
	Atlas Minerals	Ivy Mine, Southwest Lisbon Valley, Big Indian Mining District	No Production
	Atlas Minerals	Last Chance Mine, Brown's Hole, Big Indian Mining District, Moab Uranium District	No Production
	Atlas Minerals	Linda Mujer Mine, Lisbon Valley, Big Indian Mining District, Monticello Uranium District	No Production
	Atlas Minerals	Louise Mine, Lisbon Valley Area	No Production
	Atlas Minerals	Maria, La Sal Area	No Production
	Atlas Minerals	Dorothy May, Ruby Bell, Lisbon Valley Area	No Production
	Atlas Minerals	Pandora Mines, La Sal Area	1,000-100,000
	Atlas Minerals	Patti Ann, La Sal Area	100-1,000

Table V-2 Con't
 Uranium Production and Properties in Utah
 (1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Atlas Minerals	Pear, Lisbon Valley Area	No Production
	Atlas Minerals	Poor Boy, Paradox Uranium District	No Production
	Atlas Minerals	Radium King, West Channel, White Canyon Uranium District	No Production
	Atlas Minerals	Reprise, Lisbon Valley Area	No Production
	Atlas Minerals	Rim Shaft, Columbus, Humbug, Dry Valley, Monticello Uranium District	1,000-100,000
	Atlas Minerals	Skidmore Mine, Skunkovich, Bobcat, Bobtail Mines, Lisbon Valley, Big Indian Mining District, Monticello Uranium District	1,000-100,000
	Atlas Minerals	Spider-Locust Mine, Monticello Uranium District	100-1,000
	Atlas Minerals	Standatd, White Canyon Uranium District	1,000-100,000
		Windfall Mine	100-1,000
	Atlas Minerals	3 Step Mine, Southeast Lisbon Valley Area	No Production
	Atlas Minerals	Wood Mine, Southwest Lisbon Valley, Big Indian Mining District	1,000-100,000
	Big Indian Uranium Corp.	Cooper, King, Dandy, Jim, Mineral Point, Piute, Mond, Big Indian Mining District	No Production
	Black Hat Mining Co.	Black Hat Mine, La Sal Creek, Paradox Valley Mining District, Paradox Uranium District	No Production
	Black Hat Mining Co.	Blue Cap, Big Joe, Paradox Valley Mining District, Paradox Uranium District	No Production
	Black Hat Mining Co.	Ella, Jimbo Bob, La Sal District, Paradox Valley Mining District	No Production

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Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Black Hat Mining Co.	Jimbo Bob Mine, Dry Valley, Big Indian Mining District, Monticello Uranium District	No Production
	Black Hat Mining Co.	Joan Mine, Paradox Valley Mining District, Paradox Uranium District	No Production
	Black Hat Mining Co.	Johnnie, Paradox Valley Mining District, Paradox Uranium District	No Production
	Black Hat Mining Co.	Little Joe, Paradox Valley Mining District, Paradox Uranium District	No Production
	Black Hat Mining Co.	May, Paradox Valley Mining District, Paradox Uranium District	No Production
	Black Hat Mining Co.	Willis, Paradox Valley Mining District, Paradox Uranium District	No Production
	Calvin Black Enterprises	Nap and Markey, Poochie, Red Canyon, White Canyon Mining District, White Canyon Uranium District	1,000-100,000
	Blakes Mining Co.	Smoky Mine, White Canyon Uranium District	1,000-100,000
	Blasting & Mining Inc.	Dusty, Ike Mines	No Production
	Leroy Bowerman	Blue Bird, Cottonwood Wash, Big Indian Mining District, Monticello Uranium District	No Production
	Sharon M. Bullard	Jills, Auds, Shelley Mines Four Corners Mining District	100-1,000
	Bullseye Uranium Corp.	Bullseye Mine, Red Canyon Mining District, White Canyon Uranium District	No Production
	Jim Butt	Bullseye, Salt Cedar, Paradox Uranium District	No Production
	Jim Butt	Cameo Mine, Yellow John Mine, Camel Mine	100-1,000
		Give Away Mine, White Canyon, Daisy Mine, Yankee Girl Mine, White Canyon Uranium District	1,000-100,000

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Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Canyonlands Uranium Inc.	Pete Mine, Lower Montezuma Canyon, Monticello Uranium District	No Production
	Century 21 Mining, Inc.	Jomac Mine	100-1,000
	C.B.C. Mining Co.	Gizmo Mine, Red Canyon Mining District, White Canyon Uranium District	Data Withheld
	Gleghorn and Washburn Mining Co.	Little Joe, East of La Sal Junction	No Production
	Dale Dillon	Hole-in-the-Rock Mine	100-1,000
	Dolores-Bench Limited Partnership	South Lisbon Valley Mines, Lisbon Mining District	1,000-100,000
	Energy Fuels Nuclear,	Hillside-Gismo, Bears Ears, Maybe, West of Blanding	100-1,000
	Emery Coal Inc.	Woodinshoe Mine	100-1,000
	Energy Fuels Limited	Yankee Girl, Red Canyon Mining District, Yankee Girl Mine Glade	1,000-100,000
	Even Odds Inc.	Pete Group, Montezuma Canyon, Paradox Uranium District	No Production
	Foote Mineral Co.	Hyde and Duckett Group, Garbutt Group, Monticello Uranium District	No Production
	Foote Mineral Co.	Last Chance Mine, Cottonwood Wash, Cottonwood Canyon Mining District, Monticello Uranium District	No Production
	Foote Mineral Co.	Spring Creek Mine, Cottonwood Wash, Cottonwood Canyon Mining District, Monticello Uranium District	No Production
	Fritz-Erickson Mining Co.	Locust Group, Monticello Uranium District	No Production
	C. Alfred Frost	Horseshoe	1-100
	Garbutt Estate	Lower Cottonwood Mine Cottonwood	1,000-100,000

Table V-2 Con't.

Uranium Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Genral Electric Uranium Management Corp.	G.E.U.M. Mine, Northeast of La Sal Junction	Data Withheld
	Geo Energy Resources	Fire Fly, Pigmy, Butterfly, Blow Fly, Dragon Fly, Blue Fly, Wild Pigeon, June Bug, Deer Fly, Moonbeam, Grey Dawn, Little Don, Little Peter, La Sal Creek, Paradox Valley Mining District, Paradox Uranium District	No Production
	Gramich Exploration Co.	Blue Jay Mine, Brown's Hole, Big Indian Mining Distrtict, New Shell, Rhea Mines, Yellow Circe Area, 15 Mi Southeast of Moab	No Production 1-100
	Charles Hughs,	Avalance, Paradox Uranium District	No Production
	J.R.J. Mining Co.	Alice Mine, Lisbon Valley, Big Indian Mining District, Monticello Uranium District	1,000-100,000
	E. J. Johannsen and C. Tatum	Joker, Montezuma Creek Mining Area	No Production
	K. Enterprises	Joker, Avalance, Cliff House, Montezuma CANYon, Paradox Uranium District	No Production
	Kelmine Corp	Oljeto Mine, Monument Valley Area, South of Organ Rock	No Production
	Kinder, Mistler, & Raish Ouray Uranium Co.	Yellow Circle Group, Fraction Mine, Yellow Circle-Cane Canyon, Big Indian Uranium District	No Production
	James L. Lammert and Bill Gurgess	Lammert-Burgess Mine, Southwest of Moab	No Production
	Royce R. Latimer	Red Devil, Cane Creek, Paradox Uranium District	100-1,000
	Laura Mining Co.	Laura Mine	1,000-100,000
	Look Mining Co.	Cliff House, Cottonwood, Avalance	No Production
	Marmac Resources Co.	Little Mae, Monticellow Uranium Disctrict	1,000-100,000

Table V-2 Con't

Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	D.C. McDougald and Tom Patterson	Lone Star, Southwest Lisbon Valley, Paradox Uranium District	No Production
	Marion McGehee and Andy Hayes	Lucky Strike Mine, Montezuma Canyon, Monticello Mining District, Monticello Uranium District	No Production
	Mineral Energy Co.	Found, Cottonwood Wash, Paradox Uranium District	No Production
	Mineral Energy Co.	Fry, White Canyon Uranium District	No Production
	Mineral Energy Co.	Hideout, Monument Upwarp Area, White Canyon Uranium District	No Production
	Mineral Energy Co.	N Point-Goneaway, White Canyon Uranium District	No Production
	Mineral Energy Co.	Saddle Scenic, Mounument Upwarp, White Canyon Uranium District	No Production
	Mineral Energy Co.	Straight Shot, White Canyon Area, White Canyon Uranium District	No Production
	Mineral Energy Co.	White Canyon, White Canyon Uranium District	No Production
	Minerals Recovery Corp.	South Lisbon Valley Mine	No Production
	Minerals West Inc.	MiVida, Joker Properties, Lisbon Valley Area	1,000-100,000
	Monticello Minerals	Maybe Mine	100-1,000
		Monticello Mine	100-1,000
	Murphy Mining Co.	Dime Mine	1,000-100,000
		Roanoke Mine, Monticello Mining District, Monticello Uranium District	1-100
Nelson Mining Co.		Fry, Fry Canyon Area	100-1,000
Milton C. Nielson		Red Patch, Dry Valley, Paradox Uranium District	No Production
Milton C. Nielson		Sunset, Dry Valley, Paradox Uranium District	No Production

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Uranium Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Ralph J. Noonan	Cy's Monument Mine, Rebel, Elk Ridge	No Production
	Ouray Uranium Co.	Carol B., La Sal Area, Paradox Uranium District	No Production
	Ouray Uranium Co., Atlas Minerals Corp.	Mi Vida Incline, Big Indian Mining District	No Production
	Kenneth A. Partridge	State Lease, Big Indian Uranium District	No Production
	Petro Nuclear Ltd.	Bluff Group, Paradox Uranium District	No Production
	Plateau Mining Co. H. W. Balsley	Yellow Circle Mine, Kane Springs Area, Big Indian Uranium District	1,000-100,000
	Ranchers Exploration & Development Corp.	Small Fry Mine, Big Indian Mining District	1,000-100,000
	Rio Algom Corp.	Mining and Milling Complex-Susan, Jean, Audrey, South Block, Lisbon Mines Properties, La Sal Junction, Lisbon Valley, Big Indian Mining District	100,000 Or More
	W. W. Rockwell	Laura Bell Incline	100-1,000
	S. S. Mining Co.	Old Rattler, Frisco, Geneva Mines. Monticello Uranium District	No Production
	Clyde R. Sanchez	Dusty, Montezuma Creek Mining District	1-100
	William B. Redd, Shumway Bros.	Springwater, Cottonwood Canyon Mining District, Monticello Uranium District	No Production
	Lee, Glen, and Eugene Shumway	Blue, Abajo Mountains, Monticello Mining District, Monticello Uranium District	No Production
	Redd & Shumway	Blue Lizzard Mine, Red Canyon Mining District, White Canyon Uranium District	No Production

Dan Shumway

Long Shot Mine

100-1,000

Deloy Shumway

Strawberry Mine, Monticello Mining
District, Monticello Uranium District

1,000-100,000

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Uranium Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Jerry Holladay and Eugene Shumway	Steamboat	1-100
		King Edward II Mine, Monticello Mining District	100-1,000
	Shumway Mining Co.	McCormick Drift, Paradox Uranium District	No Production
	Kenneth D. Shumway	McKenzie Mine	1,000-100,000
		North Elk Mining District, Pay Day Mine	1-100
		Posey Mine, Red Canyon Mining District	1,000-100,000
		Avalanche, Giveaway Yankee Girl Mines	100-1,000
	Seth Shumway	V-8 Butler Wash Area	1,000-100,000
		Gold Butte, Cottonwood Wash, Paradox Uranium District	100-1,000
	Grant L. Shumway	Rex Mines, Elk Ridge, White Canyon Mining District, White Canyon Uranium District	No Production
	Plateau Mining and Shymway Bros.	Royal Flush, Cottonwood Wash, Paradox Uranium District	No Production
	Shumway Bros.	Simpatoca, Marilee, Cottonwood, Cottonwood Canyon Mining District, Monticello Uranium District	1,000-100,000
	Larry Shumway Mining Co.	Yellow Circle, La Sal Area, Paradox Uranium District	No Production
	Silver Eagle Mining Co.	Last Hope, Paradox Uranium District	No Production
	Small Mining Co.	Snowball, La Sal Area, Paradox Uranium District	No Production
	Lowell Staats Mining Co.	Calliham Mine, Monticello Uranium District	No Production
	Lowell Staats Mining Co.	Sage, Dry Valley, Paradox Uranium District	No Production
	Clayton Stocks	Old Rattler Mine, Geneva	1,000-100,000
		Geneva, Exchequer	100-1,000

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Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Joe Stocks Mining Co.	Dimlight Mine SL, South of Moab, Paradox Mining District, Southwest of Kane Springs	100-1,000
	Texstar Corp.	Oaki Mine, Elk Ridge, White Canyon Mining District, White Canyon Uranium District	No Production
	Texstar Corp.	Rebel Mine, Utah State Lease, Deer Flats, White Canyon Mining District, White Canyon Uranium District	No Production
	Trio Industries Inc.	Wee Hope, Monument Upwarp, White Canyon Uranium District	100-1,000
	Twentieth Century Mining Co.	T-C-E Mine	No Production
	Union Carbide Corp.	Union Carbide Properties, Deremo, La Sal-Snowball, Wilson, Silver Bell, La Sal and Lisbon Valley Areas	1,000-100,000
	Uranium Production Co.	Monte Cristo, Monticello Uranium District	1,000-100,000
	Uranium Resource & Development	Uranium Resources Mine, South of Round Mountain, Manti-La Sal National Forest	No Production
	Utah Colorado Development Co., and Paradox Mining Co.	Indian Creek Mine, Indian Creed, Monticello Mining District, Monticello Uranium District	No Production
	Vanadium Queen Corp. and Rice Development Co.	Big Joe Mine, La Sal Creek, Paradox Mining District, Paradox Uranium District	No Production
	Vanadium Corp. of America	Easter Mine, Lower Cottonwood Wash, Monticello Mining District, Monticello Uranium District	No Production
	James D. Warden	Rhea Mine	100-1,000
	Wegner & Houston, Walter M. Houston	Rainbow Dedge, Indian Creed, Monticello Uranium District	No Production
	Wegner, Vaselik, & Hammond	Green Rock Mine, Monticello Mining District, Monticello Uranium District	No Production

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Uranium Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Annual Production (In Tons)</u>
San Juan (cont.)	Williams Inc.	Glade Mine & Claims, Open Pit, Elk Ridge Area, Big Indian Mining District	1,000-100,000
	Woodmont Inc.	Rattlesnake, Big Indian Mining District, Rattlesnake Ranch	1,000-100,000
	Worldwide Energy Corp.	Frisco Group, Paradox Mining District	No Production
	Yuba Development Corp.	Cedars, Deer Flats, White Canyon Mining District, White Canyon Uranium District	No Production
	Yuba Development Corp.	Charlie, Dee Flats, White Canyon Mining District, White Canyon Uranium District	No Production
	Yuba Development Corp.	Goneaway Mine, White Canyon Mining District, White Canyon Uranium District	No Production
	Yuba Development Corp.	Hideout, Deer Flats, White Canyon Mining District, White Canyon Uranium District	No Production
	Yuba Development Corp.	North Point Mine, White Canyon Mining District, White Canyon Uranium District	No Production
	Yuba Development Corp.	W.H. Mine, Deer Flats, White Canyon Mining District, White Canyon Uranium District	No Production
Washing- ton	Coastal Mining Co.	Apex, Morning Star, Last Chance, Surprise, Ella May, Tutsagubet Mining District	No Production
Wayne	Riter Effer	Mo Dock Mine	No Production
	Green Hornet Mining Corp.	Green Hornet Ventures, South of Caineville	No Production
	Minerals Recovery Corp.	Wild Horse, North Knob	No Production
	R. L. Roper	Poor Boy Mine, Henry Mountains Uranium District	No Production

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Uranium Production and Properties in Utah

(1979)

Source: Carlton H. Stowe, Utah Mineral Industry Operator Directory 1979 (Salt Lake City, Utah: Utah Geological and Mineral Survey, June 1979).

- (1) Before the nuclear fuel can be used, the fuel must undergo a complex series of processing and fabrication steps to produce useful nuclear fuel elements.
- (2) Nuclear fuels are not completely expended when used in a reactor but the fuel is removed, purified, replenished and refabricated periodically.

"These unique characteristics establish a fuel cycle that includes exploration, mining, milling, conversion, enrichment, fabrication, recovery and reprocessing, transportation, and waste disposal."⁴

Table V-3 presents a summary of some of these nuclear fuel cycle characteristics. Figure V-2 presents a summary of the fuel cycles for Light Water Reactor Fuel Cycle (LWR), Liquid Metal Fast Breeder Reactor Fuel Cycle (LMFBR) and High Temperature Gas Cooled Reactor Fuel Cycle (HTGR).

The following summarizes these fuel cycles:

LWR Fuel Cycle

The fuel cycle for LWRs starts with the mining and milling of uranium ore to obtain yellowcake (U_3O_8). The yellowcake is shipped from the mill to a conversion plant where it is converted into uranium hexafluoride (UF_6), a solid at room temperatures. The UF_6 is shipped to an ERDA-operated enrichment facility where the ratio of the uranium isotopes (U-235 and U-238) is changed. The portion of the UF_6 that contains a higher than natural percentage (or assay) of ^{235}U is the enriched uranium and the portion that contains the lower assay is the depleted uranium (or tails). The enriched uranium is sent to a fuel fabrication plant where the UF_6 is converted into uranium oxide (UO_2) powder and compacted into small cylindrical pellets. The fuel assembly consists of precisely aligned cylinders that contain the fuel pellets. In this form the uranium is ready for use in a reactor. Periodically (usually once a year) LWRs are shut down and refueled. At that time, 25 to 35 percent of the fuel is replaced. The spent fuel is intensely radioactive and is stored at the power plant site for several months before shipping to a reprocessing plant. The spent fuel contains, in addition to U-235 and U-238, isotopes of plutonium and other radioactive materials. The reprocessing procedure separates the uranium and plutonium from the spent fuel and prepares the remaining wastes for storage. The uranium is still slightly enriched (0.84 to 0.94 percent) and is shipped back to the enrichment plant for recycling.

In the LWR fuel cycle shown in Figure V-2, the dashed line indicates the path the plutonium would follow if it were to be recycled for use as LWR fuel. At the present time, plutonium is stockpiled for its anticipated future use in both LWRs and LMFBRs. The Nuclear Regulatory Commission (NRC) has proposed to announce its position on plutonium recycle early in 1977.

Table V-3

Description of Selected Nuclear Fuel Cycle Characteristics

<u>Fuel Cycle</u>	<u>Description</u>
Conversion	<p>Conversion of the yellowcake (U_3O_8) to uranium hexafluoride (UF_6) takes place at two plants in the United States. These plants can process 22,400 tons per year of yellowcake and produce 28,100 tons per year of UF_6. Planned expansion of an existing facility and the construction of a new plant will double the U.S. conversion capacity.¹ The costs of conversion amount to about 1.5 percent of the cost of the total fuel cycle and have little effect on the cost of power produced.</p>
Enrichment	<p>Enrichment is a major component of the fuel cycle. ERDA operates three gaseous diffusion plants that take UF_6 from conversion plants and reprocessing plants and alter the isotopic mixture of U-235 and U-238. The gaseous diffusion process is both capital and power intensive. It is common practice to measure the capacity and productivity of the enrichment process in terms of separative work units. A separative work unit (SWU) is a measure of the effort expended in the plant to separate a quantity of uranium of a given assay into two components, one having a higher percentage of U-235 and one having a lower percentage. Separative work is generally expressed in kilograms to give it the same dimension as material quantities. However, it is common practice to refer to a kilogram SWU simply as an SWU. For example, if a single kilogram of uranium enriched to 3.0 percent U-235 were produced starting with natural uranium (0.711 percent U-235) and with depleted (or tails) uranium of 0.275 percent U-235, then 3.6 SWU would be required. If there was any change in the feed assay, the tails assay or the enrichment assay, the number of SWU would change. For the example cited, 6.25 kilograms of natural uranium are needed to produce a single kilogram of 3.0 percent enriched uranium.² Lowering the tails assay would decrease the demand for natural uranium but would increase the separation work required. ERDA operates its diffusion plants at 0.25 percent tails assay.³</p> <p>The three enrichment plants--located at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio--operate interdependently with the complex having a capacity of 17.2 million SWU per year in 1973. Operating at full capacity, the three plants consume 6,000 MWe. Because the demand for enrichment services will grow with the nuclear power industry, ERDA is pursuing</p>

two programs to increase the diffusion plant capacities. The Cascade Improvement Program (CIP) will increase capacity by 33 percent, and the Cascade Upgrading Program (CUP) will raise that another 21 percent for a total capacity of 27.7 million SWU per year by 1980. At this capacity, the power demand of the complex will be about 7,400 MWe.⁴

Because of the limitations on electric power available, the enrichment facilities have been operating well below full capacity. The FY 1972 and FY 1973 power levels and production levels and the projected FY 1974 figures for the enrichment plants are shown in Table XII-6. Full production will not be achieved until about 1978.

The projected demands for separative work are shown in Table XII-7. These projections were made assuming a 0.30 percent tails assay with plutonium recycle in 1977. Without plutonium recycle, the demand for enrichment services will increase.

The current cost of enrichment is \$61.30/SWU for fixed-commitment, long-term contracts and \$66.75/SWU for requirements-type contracts. The cost of enrichment has been \$59.05/SWU for fixed-commitment contracts before October 1, 1976 and \$42.10/SWU before August 20, 1975. The price of requirements-type contracts will have increased to \$69.80/SWU on January 27, 1977.⁵ By 1981, ERDA plans to increase the cost of enrichment services to about \$76/SWU.⁶ An increase from \$42 to \$76/SWU increases the fuel cycle costs by about 0.9 mills/kWh.⁶

ERDA plans an expansion of its Portsmouth, Ohio, gaseous diffusion plant. After completion of CIP and CUP in 1981, the capacity will have been increased from 5.2 to 8.4 million SWU per year. The proposed increase in plant size will add 8.75 million SWU per year by the mid-1980's and will require 3,500 to 3,700 MWe of additional power.⁷

The future expansion of enrichment facilities in the United States is a matter of Congressional debate. Several proposals have been made by private industry to enter the enrichment market.

Two alternatives to gaseous diffusion are under investigation in the United States. The first, the gaseous centrifuge, is at the pilot-plant stage. This process consumes only 10 percent of the power of a gaseous diffusion plant for the same separative work and has been demonstrated to be effective in both the United States and Europe. The second is isotope separation by lasers. This is still in the experimental stage and can only be considered to be a possible long-term enrichment method.

Table V-3 Con't

Fabrication

There are five operating fuel fabrication plants in the United States with a total capacity of 3,025 tons of uranium per year. Industry plans will add a capacity of 6,000 tons of uranium per year by 1980.⁸ The fabrication facilities convert the UF_6 from the enrichment plant to UO_2 . The UO_2 is formed into pellets and sintered before loading into zircaloy or stainless steel tubes which are welded shut. The completed fuel rods are assembled into fuel element arrays before shipping to a nuclear power plant.

**Reprocessing and
Waste Disposal**

During reprocessing of spent fuel from nuclear power plants, the usable fissile materials are recovered and the waste materials are separated for storage. For a light water reactor, the recovered uranium is still slightly enriched and is shipped to an enrichment facility where it serves as feedstock. For each ton of uranium reprocessed, approximately 3 grams of plutonium are recovered and stored.

No fuel reprocessing plants are in commercial operation, and power plants are storing spent fuel at their plant sites until reprocessing plants enter operation. The Nuclear Fuel Services plant in West Valley, New York, was in operation from 1966 to 1971 when it was shut down for modification and expansion. It is not expected to reopen. The Barnwell Nuclear Fuel Plant in South Carolina may be able to start operating in 1981. The Barnwell plant has a projected capacity of 1,5000 metric tons per year. While in operation, the Nuclear Fuel Services plant charge about \$35,000 per ton of uranium processed. The reprocessing costs are likely to increase fourfold, increasing the fuel cycle cost by about 0.4 mills/kWh.

The management of nuclear wastes is an unsettled issue. Commercial high-level wastes are stored in liquid form in underground tanks. ERDA is continuing its investigations into methods of storage of these wastes, including solidification. In February 1976, ERDA dropped plans for a Retrievable Surface Storage Facility (RSSF), a nonpermanent solution to the high level waste storage problem. Waste management is now geared to solidification with geologic isolation. The current program calls for the construction of a Bedded Salt Pilot Plant (BSPP) for safe, terminal storage. This is the approach that has been taken in Europe.

Table V-3 Con't

- 1 "Task Force Report on Nuclear Energy," Project Independence, November 1974, and Nuclear News, April 1974.
- 2 AEC Gaseous Diffusion Plant Operations, U.S..Atomic Energy Commission, OR0-684, 1972.
- 3 Energy Daily, September 9, 1976.
- 4 "Task Force Report on Nuclear Energy," Project Independence, November 1974 and Vincent V. Abajian and Alan M. Fishman, "Supplying Enriched Uranium," Physics Today, August 1973, pp. 23-29.
- 5 Information from ERDA, Vol. 2, No. 30, August 6, 1976.
- 6 "Task Force Report on Nuclear Energy," Project Independence, November 1974.
- 7 Information from ERDA, Vol. 2, No. 41, October 22, 1976.
- 8 "Task Force Report on Nuclear Energy," Project Independence, November 1974.

Source: Energy Sourcebook

Figure V-2

LWR, LMFBR and HTGR Fuel Cycles

LIGHT WATER REACTOR FUEL CYCLE

LIQUID METAL FAST BREEDER REACTOR FUEL CYCLE

HIGH TEMPERATURE GAS-COOLED REACTOR FUEL CYCLE

LMFBR Fuel Cycle

The LMFBR fuel cycle in Figure V-2 uses plutonium as a fuel. The U-238 in the natural uranium that serves as the resource base provides the fertile material from which the plutonium is bred. The unique feature of the LMFBR fuel cycle is that more plutonium is bred from the U-238 than is consumed in the reactor. In the sense that plutonium is the fissioning material, more fuel is produced than consumed and the excess plutonium can be used for other reactors such as the light water reactor.

HTGR Fuel Cycle

The HTGR fuel cycle in Figure V-2 is based on the use of both thorium and uranium. The uranium used as a fuel in the HTGR is highly enriched (93.15 percent U-235) and is in the form of uranium carbide (UC_2). Excess neutrons from the U-235 fission are absorbed by the thorium nuclei in ThC_2 and U-233 produced. The U-233 is fissile and serves as a fuel for the HTGR.

Tables V-4 and V-5 present a summary of nuclear reactor characteristics. Currently, a nuclear energy center is being examined at a Green River, Utah site. The reader is referred to a preliminary analysis of this subject which was conducted by the State Energy Office (See Preliminary Analysis of the Study of a Nuclear Energy Center at Green River, Utah).

Resource Development Requirements

Considerable analysis has been conducted which examines the resource requirements for developing a nuclear power plant. Specific nuclear power plant siting criteria as presented by Geoffrey G. Eichholz in his book the Environmental Aspects of Nuclear Power includes the following general factors or categories: (1) technical factors, (2) physical and environmental factors, (3) and socio-economic factors. Specific development of these categories is shown in Table V-6.

The annual U_3O_8 energy resource requirements for a 1000 MW nuclear plant is as follows:

Table V-4

Summary of Nuclear Reactor Characteristics

Both the boiling water reactor (BWR) and the pressurized water reactor (PWR) are fueled with slightly enriched UO_2 and are cooled by ordinary water. In the BWR, the pressure is maintained at about 1,000 psig and steam is generated in the primary coolant loop at 545° F. The steam is passed directly through a turbine to drive an electric generator. In the PWR, the pressure in the reactor vessel is maintained at 2,050 psig and the water does not boil. The heated water passes through steam generators where the heat is transferred to water in a secondary loop at lower pressures and steam is formed for driving the turbines.

The high-temperature gas-cooled reactor (HTGR) operates on the U-223, Th-232 cycle. The primary coolant is helium, which passes through the reactor core consisting of a mixed UC_2 , ThC_2 fuel. The present generation of HTGRs is designed so that the helium coolant transfers the heat of reaction to a steam generator. The primary coolant reaches 1,400° F. and the steam is generated at 950° F. and 2,400 psig. The high operating temperatures of the HTGR give it a thermal efficiency of nearly 40 percent. If a direct-cycle, helium-driven turbine is developed, the efficiency could be increased to as much as 50 percent.¹ Because of the slowed growth rate of the electric power industry, most of the HTGRs that were on order have been cancelled and the HTGR has yet to demonstrate economic feasibility. One of the advantages of the HTGR over the BWR and PWR is its lower demand for natural uranium.

The liquid metal fast breeder reactor (LMFBR)² is being developed because of the limited size of the uranium resource base. The LMFBR utilized a high percentage of the energy potentially available in the uranium. Light water reactors and HTGRs use only 1 to 2 percent of the available energy while the LMFBR is designed to use 60 to 70 percent of that energy. The demand for U_{308} for the breeder is about one hundredth of that for LWRs. This breeder reactor uses sodium as the primary coolant. A secondary sodium loop is used to transfer heat from the primary loop to the steam loop. The overall thermal efficiency of the LMFBR is expected to be about 40 percent.

The pressurized water reactor is generally accepted as the preferred nuclear power conversion system for ship propulsion. Nuclear reactors have proven successful in terms of safety and reliability on both submarines and surface ships. The U.S. Maritime Administration operated the USS Savannah from 1962 to 1970 to demonstrate the feasibility of commercial nuclear-powered vessels. The reactor was a PWR that generated 20,000 shaft horsepower. Currently, there is only one operating commercial nuclear ship, the West German 10,000 shaft horsepower Otto Hahn. It uses an advanced PWR termed the Consolidated Nuclear Steam Generator (CNSG) in which the primary coolant flow is entirely within the reactor pressure vessel.³ Economics in the maritime industry do not support commercial development of fleets of nuclear merchant ships.

Table V-4 Con't

- ¹ Draft Environmental Statement Liquid Metal Fast Breeder Reactor Program,
U. S. Atomic Energy Commission WASH-1535, 1974.
- ² In nuclear reactor terminology the term "fast" designates that the
neutrons on the average have high velocities (i.e. fast neutron spectrum);
slow (or thermal) neutrons have low velocities.
- ³ The Nuclear Industry, 1973, U. S. Atomic Energy Commission, WASH-1174-73
UC-2, and R. A. Grams, W. L. Sage, and G. W. Geyer, "Fuels for Marine Steam
Propulsion," The Society of Marine Port Engineers 22nd Annual Fort Schuyler
Forum, March 1974.

Source: Energy Sourcebook, pp. 345-346

Table V-5

NUCLEAR REACTOR CHARACTERISTICS^a

<u>Characteristic</u>	<u>BWR</u>	<u>PWR</u>	<u>HTGR</u>	<u>LMFBR</u>
Thermal efficiency (percent)	34	33	40	40
Raw material demand U ₃ O ₈ (tons)	180	190	100	1.62 ^b
Raw material demand ThO ₂ (tons)			8.6	
Enrichment demand ^c (SWU)	84000	94000	67000	
Fresh fuel assay (percent U-235)	2.7	3.2	93	
Spent fuel assay (percent U-235)	0.8	0.9		
Reprocessing demand (tons)	30	27	11	21
Plutonium production (tons)	0.18	0.19		0.31
Primary loop pressure (psig)	1000	2050	700	200
Primary loop temperature (°F)	545	600	1400	1000
Steam loop pressure (psig)	d	800	2400	1450
Steam loop temperature (°F)	d	500	950	900

^aFor 1000 MWe plant, steady state conditions, 75 percent plant factor, no plutonium recycle except in LMFBR.

^bUranium feed can consist of depleted tails in stockpile, no enrichment needed.

^cTails assay 0.30 percent.

^dThere is no secondary loop for a BWR.

Source: Nuclear Power Growth 1974-2000, U.S. Atomic Energy Commission, WASH-1139, 1974; AEC Gaseous Diffusion Plant Operations, U.S. Atomic Energy Commission, ORO-684, 1972; The Nuclear Industry 1973, U.S. Atomic Energy Commission, WASH-1174-73 UC-2; and Draft Environmental Statement Liquid Metal Fast Breeder Reactor Program, U.S. Atomic Energy Commission, WASH-1535, 1974.

Table V-6

Nuclear Power Plant Siting Criteria

I. Technical Factors

- A. Need for power plant
- B. Proximity to load centers
- C. Size of generating system
- D. Type of power plant
- E. Number of steam supply systems
- F. Highway, rail and water access
- G. Lead time considerations
- H. Cooling water needs and availability
- I. Fuel Supply
- J. Plant safety and security

II. Physical and Environmental Factors

- A. Land requirements for the plant, fuel storage, waste disposal, switchyard and transmission lines.
- B. Condenser cooling water, reservoir needs, water resources, water quality, and thermal pollution.
- C. Cooling tower effects and alternatives.
- D. Foundations, which includes geology, water table, hydrology, seismology and soil mechanics.
- E. Hydrology: interference with drainage patterns, flooding hazards and contamination.
- F. Meteorology and air pollution, which include a study of normal weather patterns, storm and tornado frequency, and the site's relationship to built-up areas.
- G. Radiological safety including land use and access restrictions.
- H. Specific site conditions encountered with ocean frontage, underground and offshore sites.
- I. Effects on fish and wildlife.
- J. Effects on construction activities.

III. Socio-economic Factors

- A. Effect on community planning
- B. Taxes and land values
- C. Amenities and services for employees
- D. Amenities and recreational considerations for the Public.
- E. Aesthetics, such as appearance of plant and power lines.
- F. Wildlife protection.
- G. Preservation of archaeological and historical sites.
- H. Present and projected population patterns.
- I. Multipurpose plant siting.
- J. Economic impact of air or water pollution.
- K. Industrial development.
- L. Transportation needs.

Source: Geoffrey G. Eichholz. Environmental Aspects of Nuclear Power
(Ann Arbor Science, Ann Arbor, Michigan: 1977), pp. 437-438.

Boiling Water Reactor	180 tons
Pressurized Water Reactor	190 tons
High-Temperature, Gas-Cooled Reactor	100 tons
Liquid Metal Fast Breeder Reactor	1.62 tons

(See Table V-5.)

The air quality and water quality requirements for a nuclear power plant are summarized in Appendix A.

Potential Environment and Socio-Economic Impacts

Perhaps the most significant environmental concern of a nuclear power plant is the protection of the public against harmful exposure to ionizing radiation.⁶ "Without exception, nuclear power plants have been judged by the AEC on a case-by-case basis; thus, no general assessment can determine the acceptability of a given reactor at a given site."⁷

Specific environmental impacts related to a nuclear power plant include at least the following: (1) water quality impact, (2) terrestrial biological impact, (3) aquatic biological impact, (4) construction effects, (5) aesthetics, (6) air quality impact, (7) noise impact, (9) transmission system routing, and (10) impact on fuel delivery corridors.⁸

Some analysts categorize socio-economic impacts into primary internal costs, temporary external costs and long-term external costs.⁹ The following summarizes these costs:

Primary Internal Costs

- (1) Capital costs of land acquisition and improvement.
- (2) Capital costs of facility construction.
- (3) Incremental capital costs of transmission and distribution facilities.
- (4) Fuel costs including spent fuel disposition.
- (5) Other operating and maintenance costs including license fees and taxes.

- (6) Plant decommissioning costs
- (7) Research and development costs associated with potential future improvements of the facility and its operation and maintenance (including backfitting).

Temporary External Costs

- (1) Shortages of housing.
- (2) Inflationary rentals or prices.
- (3) Congestion of local streets and highways.
- (4) Noise and temporary aesthetic disturbances.
- (5) Overloading of water supply and sewage treatment facilities.
- (6) Crowding of local schools, hospitals, or other public facilities.
- (7) Overtaxing of community services.
- (8) The disruption of people's lives or the local community caused by acquisition of land for the proposed site.

Long-Term External Costs

- (1) Impairment of recreational values (e.g., reduced availability of desired species of wildlife and sportfish, restrictions of access to land or water areas preferred for recreational use).
- (2) Deterioration of aesthetic and scenic values.
- (3) Restrictions on access to areas of aesthetic and scenic values.
- (4) Degradation of areas having historic, cultural, natural or archaeological value.
- (5) Removal of land from present or contemplated alternative uses.
- (6) Creation of locally adverse meteorological conditions (e.g., fog from cooling towers or cooling ponds).
- (7) Creation of noise, especially by mechanical draft cooling towers.
- (8) Reduction of Regional product due to displacement of persons from the land proposed for the site.
- (9) Lost income from recreation or tourism that may be impaired by environmental disturbances.
- (10) Lost income attributed to environmental degradation.

- (11) Increased costs to local governments for the services required by the permanently employed workers and their families.

Transportation Tradeoffs

The transportation requirements of nuclear materials at various fuel cycle stages is significantly smaller in comparison to a coal-fixed generating plant.¹⁰ Table V-7 presents a summary of the transportation parameters for a LWR Nuclear Power Plant.

Table V-7

Summary of Transportation Parameters for the LWR Nuclear Power Industry

Material	Form	Mode	Annual Quantity Shipped to Facility	Quantity per Shipment
Reactor wastes	Packaged solids	Truck Rail	3,000 drums per reactor	50 drums 150 drums
Spent fuel	Spent fuel assemblies	Truck Rail (Barge)	1,500 tonne	0.5 tonne 3.0 tonne
Reprocessing low-level wastes w/ transuranics	Packaged solids and cladding	(a)	-	-
High level wastes w/ transuranics	Solid	Rail	500 casks (141.5 m ³)	10 casks (2.88 m ³)
Plutonium oxide	Non-dispersible solid	Truck	15,000 kgb per chemical plant	30 kgb
Fabrication wastes w/ transuranics	Packaged solids	Truck	(c)	-
Recycle fuel PnO ₂ + UO ₂	Fuel assemblies	Truck	-	-
Uranyl nitrate	Liquid	Truck	500 tonne	5 tonne
Uranium oxide from mine	Powder (yellow cake)	Truck Rail	15,000 tonne	15 tonne
UF ₆ (natural)	Powder (natural U)	Truck	10,000 tonne	11 tonne (11 tonne/cask)
UF ₆ (enriched)	Powder (enriched U)	Truck	750 tonne	11 tonne (2.2 tonne/cask)
Fresh fuel	Fuel assemblies	Truck	30 tonne	3 tonne

^aMiscellaneous low and intermediate level wastes are currently stored onsite at the reprocessing plant. Decontamination of reprocessing sites upon decommissioning will probably result in shipment of these wastes to a repository.

^bVery limited quantities of plutonium have been shipped to the mixed oxide fabrication plants. In addition, the quantity of plutonium permitted in shipping containers varies widely. Thus, it is not possible to estimate the quantities in this path with any accuracy at this time. Shipment of plutonium would range from 900 kg/yr for a 30 tonne mixed oxide plant to 4,500 kg/yr for a 150 tonne plant assuming a plutonium content of 3% in the fabricated assemblies.

^cInsufficient information exists at this time to estimate these quantities. However, it is suspected volumes will be large with plant startups and then decrease gradually.

Source: Geoffrey G. Eichholz, Environmental Aspects of Nuclear Power (Ann Arbor Science, Ann Arbor, Michigan; 1977), p. 479.

Footnotes-Section V

¹Utah Geological and Mineral Survey, January 1, 1980.

²National Electric Reliability Council, Fossil and Nuclear Fuel for Electric Utility Generation Requirements and Constraints, 1977-1986 (National Electric Reliability Council: August 1977), p.6.

³Energy Sourcebook p. 340.

⁴Ibid.

⁵Ibid., pp. 340 and 342.

⁶Ibid., p. 465-466.

⁷Ibid., p. 466

⁸R. A. Karam and Karl Z. Morgan, Environmental Impact of Nuclear Power Plants (Pergamon Press Inc., New York: 1974), p. 21.

⁹Geoffrey G. Eichholz, Environmental Aspects of Nuclear Power (Ann Arbor Science, Ann Arbor, Michigan: 1977), pp. 632 and 634.

¹⁰Ibid. p. 477.

SECTION VI

OIL AND NATURAL GAS RESOURCES IN UTAH

Currently in the United States, the development of petroleum and natural gas power plants is illegal under U.S. law as well as under the current National Energy Act, 5.1469. As a result, there has been relatively no research or publications published in the areas discussed in this study. However, this section will present resource potential, production and location information. Appendix H contains an annotative bibliography of the economics, environmental impacts and general information related to natural gas developments.

Utah's oil and natural gas liquids resource reserve is approximately 225 billion barrels or 25 percent of the total reserve which was initially estimated in 1907. Utah's natural gas reserves totals 1.3 trillion cubic feet or 42 percent of the initial reserves.¹ Figure VI-1 shows the location of the oil fields and gas fields by county in Utah.

Total production of the oil and natural gas fields are presented in Tables VI-1 and VI-2, respectively. Production statistics for 1979 oil and natural gas fields are shown in Tables VI-3 and VI-4. Finally, Figure VI-2 portrays the natural gas distribution system in Utah.

Figure VI-1

Oil and Gas Fields In Utah

Table VI-1

UTAH OIL FIELDS PRODUCTION

(1979)

	<u>1977 BBLs.</u>	<u>All Time Cumulative BBLs.</u>	<u>First Year Recorded Production</u>
<u>Box Elder County</u>			
Rozel Point	S.I.	2,896 (1967)	1965
<u>Davis County</u>			
Farmington	-	I.A. (1895)	1892
<u>Rich County</u>			
Hogback Ridge	-	N.P.	1977
<u>San Pete County</u>			
Joes Valley	S.I.	N.A.	1955
<u>Carbon County</u>			
Farnham Dome	-	N.P.	1931
Gordon Creek	-	S.I.	1948
Miller Creek	-	S.I.	1970
Nine Mile	-	N.P.	1962
Peters Point	20,161	71,258	1953
<u>Emery County</u>			
Ferron	301	32,773	1965
Flat Canyon	-	N.P.	1953
Last Chance	-	N.P.	1947
Woodside	I.A.	N.P.	1924
<u>Carbon-Emery Counties</u>			
Clear Creek	-	N.P.	1952
Grassy Trail	35	129,976	1961
<u>Carbon-Duchesne Counties</u>			
Stone Cabin	-	N.P.	1962
<u>Unitah County</u>			
Agency Draw	I.A.	913 (1962)	1962
Ashley Valley	180,791	18,226,440	1948
Bend	-	S.I.	S.I.
Bonanza	-	S.I.	1966
Brennan Bottom	18,482	773,052	1954
Broken Arrow	-	N.P.	1962
Buck Canyon	-	N.P.	1962

Table VI-1 Con't

	<u>1977 BBLs.</u>	<u>All Time Cumulative BBLs.</u>	<u>First Year Recorded Production</u>
Coyote Basin	35,996	699,632	1965
Crooked Canyon	-	S.I. (1978)	1978
Eight Mile	-	16,467 (1964)	1962
Evacuation Creek	-	S.I.	1977
Flat Rock	S.I.	24,960 (1976)	1963
Greater Red Wash Area			
Red Wash	1,953,503	60,859,921	1951
Refuge	I.A.	14,318 (1970)	1966
Stagecoach	I.A.	11,411 (1970)	1962
Walker Hollow	367,274	9,265,433	1953
White River	77,770	2,093,994	1962
White River, East	-	N.P.	1966
Wonsits-Wonsits Valley	1,085,658	32,830,365	1959
Gusher	1,214	68,980	1950
Gypsum Hills	20,633	252,882	1965
Halfway Hollow	10,621	70,736	1967
Horseshoe Bend	3,600	158,360	1964
Island	414	2,557	1961
Natural Buttes			
Bitter Creek	4,324	67,706	1958
Chapita Wells	-	21,168 (1970)	1953
Ouray	N.P.	9,636 (1970)	1961
Unitah Unit	N.P.	-	1960
<u>Summit County</u>			
Bridger Lake	315,115	9,371,436	1966
Elkhorn	-	N.P.	1977
Lodgepole	14,381	14,381	1977
Pineview	4,236,159	8,166,382	1975
<u>Daggett County</u>			
Clay Basin	2,278,972	133,285,296	1934
<u>Duchesne County</u>			
Castle Peak	1,689	122,200	1962
Chokecherry Canyon	S.I.*	6,224 (1970)	1959
Cottonwood Wash	S.I.	12,366 (1976)	1969
County Pool	I.A.	32,757 (1954)	1953
Duchesne	9,912	574,244	1951
Eight Mile Flat	I.A.	16,467 (1970)	1962
Flat Mesa	I.A.	55,546 (1957)	1952
Indian Canyon	N.P.	N.P.	1977
Indian Ridge	N.P.	161,011 (1972)	1966
Monument Butte	24,152	629,275	1964
Nuttex Canyon	1,806	50,536	1966

Table VI-1 Con't

	<u>1977 BBLs.</u>	<u>All Time Cumulative BBLs.</u>	<u>First Year Recorded Production</u>
Pleasant Valley	-	S.I.	1952
Rolk Creek	I.A.	1,503 (1960)	1960
Sowers Canyon	-	N.P.	1977
Starr Flat	I.A.	11,216 (1960)	1959
Oil Springs	N.P.	19,219	1964
Pariette Bench	25,366	434,530	1962
Powder Springs	-	N.P.	1965
Randlett	N.P.	5,578 (1972)	1970
River Bend	-	N.P.	1977
River Junction	7,209	130,658	1965
Rock House	978	8,570	1961
Sand Ridge	-	N.P.	1977
Seep Ridge	516	1,883	1973
Southman Canyon	S.I.	1,868 (1962)	1962
Twelve Mile Wash	I.A.	8,518 (1968)	1968
Uteland Butte	S.I.	408 (1962)	1962
<u>Dusche-ne-Unitah Counties</u>			
<u>Greater Altamont-Bluebell</u>			
Altamont	6,087,663	44,375,702	1970
Blacktail Ridge	S.I.	4,819 (1966)	1965
Bluebell	6,542,434	52,116,073	1957
Blue Bench	19,076	176,683	1972
Cedar Rim	1,164,481	6,099,987	1969
Starvation	11,221	217,847	1971
Roosevelt	39,422	3,157,596	1949
<u>Grand County</u>			
Agate	3,218	186,022	1961
Bartlett Flat	I.A.	39,393 (1964)	1961
Bar-X	-	N.P.	1956
Big Flat	S.I.	83,469 (1967)	1957
Blaze Canyon	1,623	14,137	1974
Book Cliffs	S.I.	207 (1967)	1962
Bryson Canyon	-	N.P.	1962
Bull Canyon	S.I.	10,564 (1976)	1972
Cane Canyon	S.I.	1,887 (1962)	1959
Crescent Area	-	N.P.	1941
Danish Wash	-	N.P.	1973
Diamond Ridge	-	N.P.	1963
Dust Bowl	I.A.	N.P.	1977
Eagle Monument	-	N.P.	1972
East Canyon	N.P.	2,960 (1974)	1963
<u>Greater Cisco Area</u>			
Cisco Dome	-	N.P.	1927
Cisco Springs	4,819	17,524	1971

Table VI-1 Con't

	<u>1977 BBLs.</u>	<u>All Time Cumulative BBLs.</u>	<u>First Year Recorded Production</u>
Cisco Springs, North	-	S.I.	1955
Cisco Townsite	S.I.	9,357 (1970)	1954
Cisco Wash	187	187	1976
Gravel Pile	8	2,477	1963
Harley Dome	-	S.I.	1925
Horse Point	-	N.P.	1967
Left Hand Canyon	261	20,003	1972
Long Canyon	I.A.	572,925	1962
Moon Ridge	-	N.P.	1963
Overlook	S.I.	271 (1972)	1968
Pear Park	-	N.P.	1961
Sage	S.I.	120 (1967)	1966
Saltwash	12,666	1,182,081	1961
San Arroyo	7,079	113,040	1962
Segundo Canyon	N.P.	705 (1963)	1962
Seiber Nose	S.I.	15,333 (1976)	1955
Stateline	3	3	1963
Westwater	530	12,256	1961
<u>Utah-Grand Counties</u>			
Fence Canyon	-	N.P.	1967
<u>San Juan County</u>			
Akah	3,811	455,681	1955
Alkali Canyon	I.A.	3,919 (1977)	1965
Anido Creek	8,691	689,417	1961
Big Indian	7,226	131,589	1961
Big Wash	I.A.	303,912 (1968)	1963
Bluff	22,020	1,307,912	1958
Bluff Bench	I.A.	15,264 (1961)	1957
Boundary Butte	183,290	4,124,794	1948
Broken Hills	2,289	81,559	1959
Chinle Wash	244	2,958	1959
Cleft	I.A.	3,537 (1963)	1962
Cone Rock	I.A.	945 (1960)	1959
Cotton Creek	I.A.	452 (1977)	1962
Cowboy	8,726	110,700	1968
Desert Creek	9,241	537,416	1954
Gothic Mesa	34,800	1,550,677	1957
Grassy Trail	35	126,902	1961
Grayson	S.I.	6,441 (1963)	1961
<u>Greater Aneth Area</u>			
Aneth	3,226,670	96,937,859	1956
Cahone Mesa	I.A.	75,700 (1976)	1957
McElmo Creek	3,683,108	103,171,316	1957
Ratherford	1,033,393	62,285,355	1956
White Mesa	314,949	22,524,160	1957

Table VI-1 Con't

	<u>1977 BBLs.</u>	<u>All Time Cumulative BBLs.</u>	<u>First Year Recorded Production</u>
Hatch	S.I.	16,264 (1968)	1957
Hogan	N.P.	645 (1963)	1963
Ismay	122,292	9,326,062	1956
Ismay, South	3,501	124,004	1960
Lisbon	954,982	40,595,664	1960
Little Valley	14,641	30,352	1962
*Lone Mountain Creek	I.A.	62,897	1972
Mexican Hat	3,306	92,944	1908
Patterson Canyon	7,093	7,093	1977
Piute Knoll	-	S.I.	1973
Rabbit Ears	2,582	54,068	1967
Recapture Creek	45,500	1,607,065	1958
River Bank	N.P.	1,396 (1967)	1967
Rockwell Flat	4,355	62,713	1967
Shafer Canyon	I.A.	67,556 (1966)	1962
Tohonadla	37,258	1,724,990	1958
Turner Bluff	1,687	54,232	1957
White Belly Wash	S.I.	89 (1975)	1975
Wilson Canyon	2,954	57,714	1968
Yellow Rock	1,813	75,098	1964
<u>Garfield County</u>			
John's Valley	-	1,245 (1970)	1970
Upper Valley	932,438	16,897,825	1964
<u>Washington County</u>			
Anderson Junction	I.A.	1,380 (1970)	1968
Virgin	S.I.	206,217 (1976)	1907

*Significant amount of production not recorded but consumed locally.

I.A. = Inactive

N.P. = No Production

S.I. = Shut in

Table VI-1 Con't

Undesignated Area

<u>County</u>	<u>Annual</u>	<u>All time Cumulative</u>	<u>Year</u>
Duchesne	105,807	117,581	1972
	942,872	1,010,337	1973
	-	19,144	1978
Grand	600	600	1972
	2,339	2,339	1974
	19,093	19,772	1976
	30,318	50,090	1977
	4,231	22,968	1978
San Juan	1,015	4,371	1976
	6,082	10,453	1977
Uintah	-	-	1970
	3,220	3,220	1972
	-	3,729	1974
	19,811	23,538	1975
	15,586	46,931	1976
	-	19,144	1977
	8,281	13,387	1978
Wasatch	483	483	1971

Table VI-2

UTAH NATURAL GAS FIELDS PRODUCTIONS

(1977)

	<u>1977 MCF</u>	<u>All Time Cumulative MCF</u>	<u>First Year Recorded Production</u>
<u>Box Elder County</u>			
Rozel Point	-	N.P.	1965
<u>Davis County</u>			
Farmington	-	I.A. (1895)	1892
<u>Rich County</u>			
Hogback Ridge	-	N.P.	1977
<u>San Pete County</u>			
Joes Valley	S.I.	434,382 (1970)	1955
<u>Carbon County</u>			
Farnham Dome	191,714	2,182,710	1931
Gordon Creek	-	S.I.	1948
Miller Creek	-	S.I.	1970
Nine Mile	17,190	356,703	1962
Peters Point	594,095	617,920	1953
<u>Emery County</u>			
Ferron	265,542	7,677,245	1965
Flat Canyon	I.A.	1,436,641 (1967)	1953
Last Chance	I.A.	6,500 (1949)	1947
Woodside	I.A.	N.P.	1924
<u>Carbon-Emery Counties</u>			
Clear Creek	215,412	134,544,697	1952
Grassy Trail	-	N.P.	1961
<u>Carbon-Duchesne Counties</u>			
Stone Cabin	S.I.	369,997 (1964)	1962
<u>Unitah County</u>			
Agency Draw	I.A.	740 (1962)	1962
Ashley Valley	-	N.P.	1948
Bend	-	S.I.	S.I.
Bonanza	S.I.	266,583 (1974)	1966
Brennan Bottom	4,858	1,164,924	1954
Broken Arrow	I.A.	9,918 (1976)	1962
Buck Canyon	S.I.	485,956 (1976)	1962

Table VI-2 Con't

	<u>1977</u> <u>MCF</u>	<u>All Time</u> <u>Cumulative</u> <u>MCF</u>	<u>First Year</u> <u>Recorded</u> <u>Production</u>
Coyote Basin	9,490	279,855	1965
Crooked Canyon	-	S.I. (1978)	1978
Eight Mile	-	S.I.	1962
Evacuation Creek	-	S.I.	1977
Flat Rock	I.A.	1,065 (1971)	1963
Greater Redwash Area			
Redwash	3,794,577	243,761,642	1951
Refuge	I.A.	9,931 (1970)	1966
Stagecoach	I.A.	2,078,823 (1970)	1962
Walker Hollow	482,149	20,742,547	1953
White River	8,284	5,323,061	1962
White River, East	S.I.	73,784 (1966)	1966
Wonsits-Wonsits Valley	257,424	21,021,777	1959
Gusher	-	N.P.	1950
Gypsum Hills	N.P.	22,312 (1968)	1965
Halfway Hollow	N.P.	2,542 (1969)	1967
Horseshoe Bend	135,056	13,427,644	1964
Island	413,584	3,160,068	1961
Natural Buttes			
Bitter Creek	4,408,217	44,029,010	1958
Chapita Wells	-	11,235,111 (1970)	1953
Ouray	N.P.	8,191,611	1961
Unitah Unit	N.P.	-	1960
<u>Summit County</u>			
Bridger Lake	2,925,378	21,270,411	1966
Elkhorn	-	N.P.	1977
Lodge Pole	-	N.P.	1977
Pineview	4,346,891	5,365,059	1975
<u>Daggett County</u>			
Clay Basin	4,506	307,225	1934
<u>Duchesne County</u>			
Castle Peak	1,806	130,675	1962
Chokecherry Canyon	S.I.*	6,224 (1960)	1959
Cottonwood Wash	S.I.	8,643 (1976)	1969
County Pool	-	N.P.	1953
Duchesne	3,452	198,046	1951
Eight Mile Flat	I.A.	N.P.	1962
Flat Mesa	-	N.P.	1952
Indian Canyon	N.P.	N.P.	1977
Indian Ridge	N.P.	381,429 (1972)	1966
Monument Butte	13,253	328,293	1964
Nutter Canyon	2,237	61,342	1966

Table VI-2 Con't

	<u>1977</u> <u>MCF</u>	<u>All Time</u> <u>Cumulative</u> <u>MCF</u>	<u>First Year</u> <u>Recorded</u> <u>Production</u>
Pleasant Valley	-	S.I.	1952
Rolk Creek	I.A.	2,469 (1960)	1960
Sowers Canyon	-	N.P.	1977
Starr Flat	I.A.	4,832 (1960)	1959
Oil Springs	64,720	1,931,487	1964
Pariette Bench	15,786	315,196	1962
Powder Springs	296,128	7,095,722	1965
Randlett	-	N.P.	1970
River Bend	-	N.P.	1977
River Junction	480	190,478	1965
Rock House	132,882	7,057,299	1961
Sand Ridge	-	N.P.	1977
Seep Ridge	759,721	1,829,905	1973
Southman Canyon	21,012	661,251	1962
Twelve Mile Wash	I.A.	7,175 (1968)	1968
Uteland Butte	I.A.	354,108 (1970)	1962
<u>Duchesne-Unitah Counties</u>			
<u>Greater Altamont-Bluebell</u>			
Altamont	11,399,599	61,399,214	1970
Blacktail Ridge	S.I.	11,602 (1966)	1965
Bluebell	8,567,063	52,545,552	1957
Blue Bench	73,247	492,415	1972
Cedar Rim	2,914,889	9,168,447	1969
Starvation	29,409	611,227	1971
Roosevelt	1,220	334,724	1949
<u>Grand County</u>			
Agate	531,229	2,687,406	1961
Bartlett Flat	I.A.	22,051 (1963)	1961
Bar-X	529,337	16,807,354	1956
Big Flat	S.I.	52,395	1957
Blaze Canyon	-	N.P.	1974
Book Cliffs	8,022	359,716	1962
Bryson Canyon	238,228	8,557,457	1962
Bull Canyon	-	N.P.	1972
Cane Canyon	S.I.	25,000	1959
Crescent Area	-	N.P.	1941
Danish Wash	2,187	35,182	1973
Diamond Ridge	I.A.	261,455 (1966)	1963
Dust Bowl	I.A.	N.P.	1977
Eagle Monument	-	N.P.	1972
East Canyon	374,635	5,390,567	1963

Table VI-2 Con't

	<u>1977 MCF</u>	<u>All Time Cumulative MCF</u>	<u>First Year Recorded Production</u>
Greater Cisco Area			
Cisco Dome	35,029	2,898,375	1927
Cisco Springs	N.P.	852,987 (1976)	1971
Cisco Springs, North	-	S.I. (1955)	1955
Cisco Townsite	-	N.P.	1954
Cisco Wash	29,623	98,064	1976
Gravel Pile	316	22,127	1963
Harley Dome	-	S.I.	1925
Horse Point	110,277	14,813,234	1967
Left Hand Canyon	24	59	1972
Long Canyon	I.A.	665,502	1962
Moon Ridge	39,414	1,196,414	1963
Overlook	S.I.	412,064 (1973)	1968
Pear Park	S.I.	49,937	1961
Sage	-	N.P.	1966
Salt Wash	188,717	11,556,537	1961
San Arroyo	2,903,080	67,041,304	1962
Segundo Canyon	68,259	984,361	1962
Seiber Nose	-	N.P.	1955
Stateline	48,062	1,343,071	1963
West Water	821,393	30,130,025	1961
<u>Unitah-Grand Counties</u>			
Fence Canyon	328,538	4,507,053	1967
<u>San Juan County</u>			
Akah	496	386,261	1955
Alkali Canyon	I.A.	40,085 (1971)	1965
Anido Creek	I.A.	508,406 (1970)	1961
Big Indian	1,567,171	14,787,660	1961
Big Wash	-	N.P.	1963
Bluff	37,065	2,258,543	1958
Bluff Bench	I.A.	4,593 (1961)	1957
Boundary Butte	116,168	11,443,357	1948
Broken Hills	1,471	44,059	1959
Chinle Wash	N.P.	2,681,899 (1971)	1959
Cleft	I.A.	1,031 (1963)	1962
Cone Rock	I.A.	4,553 (1960)	1959
Cotton Creek	-	N.P.	1962
Cowboy	-	N.P.	1968
Desert Creek	11,362	456,189	1954
Gothic Mesa	7,440	508,438	1957
Grassy Trail	-	N.P.	1961
Grayson	S.I.	5,331 (1963)	1961
Greater Aneth Area			
Aneth	2,299,080	91,183,174	1956
Cahone Mesa	S.I.	96,272 (1971)	1957
McElmo Creek	2,783,273	91,873,019	1957

Table VI-2 Con't

	<u>1977 MCF</u>	<u>All Time Cumulative MCF</u>	<u>First Year Recorded Production</u>
Ratherford	970,119	62,185,897	1956
White Mesa	742,360	29,343,100	1957
Hatch	S.I.	482,206 (1970)	1957
Hogan	N.P.	719 (1963)	1963
Ismay	208,026	15,605,433	1956
Ismay, South	3,162	148,580	1960
Lisbon	9,436,049	303,600,190	1960
Little Valley	1,478,036	3,002,177	1962
*Lone Mountain Creek	I.A.	42,346	1972
Mexican Hat	-	N.P.	1908
Patterson Canyon	11,509	11,509	1977
Piute Knoll	-	S.I.	1973
Rabbit Ears	16,008	154,717	1967
Recapture Creek	31,886	2,263,745	1958
River Bank	N.P.	8,774 (1967)	1967
Rockwell Flat	4,831	76,717	1967
Shafer Canyon	I.A.	63,807 (1966)	1962
Tohonadla	7,528	823,921	1958
Turner Bluff	2,400	14,600	1957
White Belly Wash	S.I.	60,154 (1975)	1975
Wilson Canyon	4,473	96,327	1968
Yellow Rock	545	45,331	1964
<u>Garfield County</u>			
John's Valley	-	N.P.	1970
Upper Valley	13,864,828	96,221,946	1964
<u>Washington County</u>			
Anderson Junction	-	N.P.	1968
Virgin	-	N.P.	1907

I.A. = Inactive

N.P. = No Production

*Active in 1978

Table VI-2 Con't

Undesignated Area

<u>County</u>	<u>Annual</u>	<u>All Time Cummulative</u>	<u>Year</u>
Duchesne	110,879	121,888	1972
	1,036,799	1,110,890	1973
	-	41,614	1978
Grand	-	-	1972
	92,847	92,847	1974
	16,313	18,262	1976
	2,328	16,792	1977
	8	11,222	1978
San Juan	-	-	1976
	100	100	1977
Uintah	31,870	31,870	1970
	2,933	2,933	1972
	45,417	98,419	1974
	52,450	147,556	1975
	37,746	187,896	1976
	-	41,614	1977
	112,445	173,505	1978
Wasatch	-	-	1971

Table VI-3

Oil Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Barrels)</u>
Box Elder	Union Petrochemical Corp.	Rozel Point Field	No Production
Carbon	Reserve Oil And Gas Co.	Peters Point Field, Jack Canyon Field	5,000-50,000
Daggett	Northwest Exploration Co.	Clay Basin Field (Storage)	1-5,000
Duchesne	Asamera Oil Co.	Altamont-Bluebell Field	5,000-50,000
	Burton-Hawks Inc.	Sowers Canyon Field	1-5,000
	G. S. Campbell	Monument Butte Field	1-5,000
	Utex Oil Co.	Blue Bench Field	1-5,000
	K. Chattin	Starvation Field, West of Duchesne	1-5,000
	Chevron U.S.A. Inc.	Altamont Field, Bluebell Field, Blacktail Ridge Field	50,000-500,000
	Diamond Shamrock Corp.	Altamont Field, Cedar Rim Field	5,000-50,000
	Diamond Shamrock Corp.	Castle Peak Field	1-5,000
	Diamond Shamrock Corp.	Monument Field	1-50,000
	Diamond Shamrock Corp.	Nutter Canyon Field	1-5,000
	Flying Diamond Oil Corp.	Altamont Field, Bluebell Field	500,000 Or More
	Gas Producing Enterprises Inc.	Bluebell Field	50,000-500,000
	Gulf Oil Corp.	Altamont Field, Bluebell Field	500,000 Or More
	Gulf Oil Corp.	Cottonwood Wash Field	No Production
	Gulf Oil Corp.	Duchesne Field	5,000-50,000
	Gulf Oil Corp.	Indian Ridge Field	1-5,000
	Husky Oil Co.	Altamont Field	50,000-500,000

Table VI-3 Con't
Oil Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Barrels)</u>
Duchesne (cont.)	Intermountain Oil Co.	Duchesne Field	1-5,000
	Koch Exploration	Bluebell-Altamont, Cedar Rim Field	500,000 Or More
	Mapco Inc.	Altamont Field	500,000 Or More
	Mountain Fuel Supply Co.	Cedar Rim-Sink Draw Field	50,000-500,000
	Oil Development of Utah	Starvation Field, Cedar Rim Field	1-5,000
	Phillips Petroleum Co.	Altamont Field	1-5,000
	Phoenix Resources Co.	Sowers Canyon Field	1-5,000
	Shell Oil Co.	Altamont Field, Bluebell Field	500,000 Or More
	Stroock, Rogers & Dymond	Monument Butte Field	1-5,000
	Sun Oil Co.	Altamont-Bluebell Field	5,000-50,000
	Texaco Inc.	Altamont-Bluebell Field	50,000-500,000
	M. M. Travis	Pleasant Valley Field	1-5,000
	Union Oil of California	Monument Butte Field, Castle Draw Area	1-5,000
	United Producing Co.	Chokecherry Canyon Field	No Production
Emery	Vern H. Bolinder	Grassy Trail Field	1-5,000
	Fossil Petroleum	Ferron Field	1-5,000
Garfield	Tenneco Oil Co.	Upper Valley Field, Little Valley Area	500,000 Or More
Grand	Altex Oil Corp.	Blaze Canyon Field	1-5,000
	Anschutz Corp.	Left Hand Canyon Field	No Production
	Anschutz Corp.	Westwater Canyon Field	1-5,000
	Atlantic Richfield Co.	San Arroyo Field	5,000-50,000
	Walter D. Broadhead	Agate Field	1-5,000

Table VI-3 Con't

Oil Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Barrels)</u>
Grand (cont.)	CC Co.	Cisco	5,000-50,000
	Consolidated Oil & Gas Inc.	Salt Wash Field	5,000-50,000
	D & D Oil Co.	Seiber Nose Field	1-5,000
	Getty Oil Co.	East Canyon Field	1-5,000
	King Oil Co.	Big Flat Field	No Production
	Willard Pease Drilling Co.	Cisco Springs Field	1-5,000
	R. R. Pumpelly	Agate Field	1-5,000
	Southern Natural Gas Co.	Long Canyon Field	5,000-50,000
	Toledo Mining Co.	Bull Canyon Field	No Production
San Juan	W. K. Arbuckle	McElmo Mesa Field	1-5,000
	Atlantic Richfield Co.	Boundary Butte Field	5,000-50,000
		Rabbit Ears Field	1-5,000
	Buttes Gas & Oil Co.	Gothic Mesa Field	1-5,000
	Consolidated Oil & Gas Inc.	Akah Field	1-5,000
		Bluff Field	1-5,000
		Desert Creek Field	5,000-50,000
		Recapture Creek Field	5,000-50,000
		Tohonadla Field	5,000-50,000
	Continental Oil Co.	Bluff Field	5,000-50,000
		White Mesa Field	50,000-500,000
	Dixckinson Oil Co.	Mexican Hat Field	No Production
	Glen A. Dow and T. Keith Marks	Recapture Creek	5,000-50,000
	Walter Duncan Oil Co.	White Mesa Field	50,000-500,000

Table VI-3 Con't

Oil Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Barrels)</u>
San Juan (cont.)	Exxon Co.	McElmo Creek Field	50,000-500,000
		Tohonadla Field	5,000-50,000
		White Mesa Field	5,000-50,000
	Jack J. Grynberg	Cahone Mesa Field	1-5,000
	Gulf Oil Corp.	Rockwell Flat Field	1-5,000
		Wilson Canyon Field	5,000-50,000
	J. W. Holmes and L & M Ventures	Turner Bluff Field	1-5,000
	Ladd Petroleum Corp.	Recapture Creek Field	5,000-50,000
	Merrion & Bayless	Bluff Field	1-5,000
		Broken Hills Field	1-5,000
		Chinle Wash Field	1-5,000
		Rockwell Flat Field	1-5,000
		Whitebelly Wash Field	1-5,000
		Wilson Canyon Field	1-5,000
		Yellow Rock Field	1-5,000
	Mesa Petroleum Co.	Little Valley	5,000-50,000
	Monsanto Co.	McElmo Mesa Field	5,000-50,000
	Willard Pease Drilling Co.	Cowboy Field	No Production
	Phillips Petroleum Co.	Ratherford Field	500,000 Or More
	Sanchez-O'Brien Petroleum Corp.	Undesignated	5,000-50,000
	Shiprock Oil Co.	Mexican Hat Field	1-5,000
	Southland Royalty Co.	Gothic Mesa Field	5,000-50,000
	Superior Oil Co., Anadarko Production Co., Southland Royalties, Continental Oil Co., Moncrief Oil Co., Exxon U.S.A., Texaco Inc., and Wilshire Oil of Tx.	McElmo Creek Unit	500,000 Or More

Table VI-3 Con't

Oil Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Barrels)</u>
San Juan (cont.)	Superior Oil Co., Exxon U.S.A.	McElmo Creek	5,000-50,000
	Texaco Inc.	Greater Aneth Unit Ismay Flodine	500,000 Or More 50,000-500,000
	Union Oil Co.	Big Indian Field Lisbon Field	5,000-50,000 50,000-500,000
	Wesgra Corp.	Mexican Hat Field	1-5,000
	Wexpro Co.	Patterson Canyon Field	5,000-50,000
	Williams Ranches	Mexican Hat Field	1-5,000
	Robert L. Wright	Anido Creek Field	5,000-50,000
Summit	American Quasar, Petroleum Co.	Pineview Field Lodgepole Field	50,000-500,000 1-5,000
	Champlin Petroleum	Pineview Field	500,000 Or More
	Phillips Petroleum Co.	Bridger Lake Field	50,000-500,000
Unitah	Amerada Hess Corp.	Coyote Basin Field	1-5,000
	Belco Petroleum Corp.	Coyote Basin Field White River Field Stagecoach Field Chapita Wells Field	1-5,000 1-5,000 1-5,000 1-5,000
	Donald W. Cannon	River Junction Field	5,000-50,000
	Chevron U.S.A. Inc.	White River Field La Point Field Bluebell Field Red Wash Field	1-5,000 5,000-50,000 1-5,000 500,000 Or More
	Clinton Oil Co.	Walker Hollow Field	5,000-50,000
	Diamond Shamrock Corp.	Coyote Basin Field Horseshoe Bend Field Refuge Field Pariette Bench Field	5,000-50,000 1-5,000 No Production 5,000-50,000

Table VI-3 Con't

Oil Production and Properties in Utah
(1979)

<u>County</u> <u>Utah</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production</u> <u>(In Barrels)</u>
	D & J Oil Co.	Roosevelt Field	5,000-50,000
	Energy Reserves Gourp	Ashley Valley Field	1-5,000
	Equity Oil Co.	Ashley Valley Field	50,000-500,000
	Exxon Corp.	Bluebell Field	5,000-50,000
		Roosevelt Field	5,000-50,000
		Walker Hollow Field	50,000-500,000
	Flying Diamond Corp.	Bluebell Field	50,000-500,000
		Halfway Hollow Field	5,000-50,000
		Roosevelt Field	1-5,000
	Gas Producing Enterprises Inc.	Bitter Creed-Natural	1-5,000
	Gulf Oil Corp.	Bluebell Field	500,000 Or More
		Wonsits-Wonsits	500,000 Or More
		Brennan Bottom Field	5,000-50,000
		Randlett Field	1-5,000
		Gypsum Hills Field	5,000-50,000
	Gilman Hill	Natural Buttes	1-5,000
	Earl Hollandsworth, Lee L. Travis	Ashley Valley Field	5,000-50,000
	R. Lacy Inc.	Ashley Valley Field	5,000-50,000
	Kenneth D. Luff	Walker Hollow Field	5,000-50,000
	Polumbus Co.	Ashley Valley Field	1-5,000
	Powell & Stone	Oil Springs Field	1-5,000
	Shell Oil	Bluebell Field	5,000-50,000
	Split Mountian Oil	Coyote Basin Field	1-5,000
	Tenneco Oil Co.	Ouray-Bitter Creek Field	1-5,000
	Texaco Inc.	Bluebell Field	50,000-500,000
		Seep Ridge Field	1-5,000
	Texas American Oil Corp.	Island Field	1-5,000
	Tripol Inc.	Ashley Valley Field	1-5,000

Table VI-3 Con't

**Oil Production and Properties in Utah
(1979)**

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Barrels)</u>
Washington	Buttes Gas & Oil Co.	Anderson Junction Field	1-5,000
	Zion Crude Oil Co.	Virgin Field	No Production

Source: Carlton H. Stowe, Utah Mineral Industry Operator Directory 1979 (Salt Lake City, Utah: Utah Geological and Mineral Survey, June 1979).

Table VI-4

Natural Gas Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Thousand Cubic Feet)</u>
Carbon	Equity Oil Co.	Farnham Dome Field	50,000-500,000
	Reserve Oil & Gas Co.	Peters Point Field, Jack Canyon Field	50,000-500,000
	Cordillera Corp.	Clear Creek Field	50,000-500,000
	Texaco Inc.	Nine Mile Canyon Field	5,000-50,000
Daggett	Mountain Fuel Supply Co.	Clay Basin Field	500,000 Or More
	Northwest Exploration Co.	Clay Basin Field	50,000-500,000
Duchesne	Burton-Hawks Inc.	Sowers Canyon Field	1-5,000
	Utex Oil Co.	Blue Bench Field	1-5,000
	K. Chattin	Starvation Field	1-5,000
	Chevron U.S.A. Inc.	Bluebell Field	50,000-500,000
	Chevron U.S.A. Inc.	Blacktail Ridge Field	500,000 Or More
	Diamond Shamrock Corp.	Cedar Rim Field	50,000-500,000
	Diamond Shamrock Corp.	Cedar Rim Field	50,000-500,000
	Flying Diamond Oil Corp.	Bluebell Field	50,000-500,000
	Gas Producing Enterprises Inc.	Bluebell Field	50,000-500,000
	Gulf Oil Corp.	Bluebell Field	500,000 Or More
	Husky Oil Co.	Altamont Field	500,000 Or More
	Koch Exploration	Bluebell-Altamont, Cedar Rim Field	500,000 Or More
	Koch Exploration	Bluebell-Altamont, Cedar Rim Field	50,000-500,000
	MAPCO Inc.	Altamont Field	50,000-500,000

Table VI-4 Con't

Natural Gas Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Thousand Cubic Feet)</u>
Duchesne (cont.)	W. A. Moncrief	Indian Canyon	1-5,000
	Mountain Fuel Supply Co.	Cedar Rim-Sink Draw Field	5,000-50,000
	Oil Development of Utah	Starvation Field, Cedar Rim Field	1-5,000
	Phillips Petroleum Co.	Altamont Field	15,000
	Shell Oil Co.	Bluebell Field	500,000 Or More
	Sun Oil Co.	Altamont-Bluebell Field	5,000-50,000
	Texaco Inc.	Altamont-Bluebell Field	50,000-500,000
Emery	Bruce A. and Evelyn M. Behling	Ferron Field	1-5,000
	Kitty Casey	Ferron Field	1-5,000
	Mountain Fuel Supply Co.	Ferron Field	50,000-500,000
Grand	Adams and Dizdar	Cisco Springs Field	5,000-50,000
	Atlantic Richfield Co.	Overlook Field, Bitter Creek Field	50,000-500,000
	Belco Petroleum Corp.	West Bit Unit, Jim Creek Unit	1-5,000
	Benson-Montin-Greer Drilling Corp.	San Arroyo Field	1-5,000
	Walter D. Broadhead	Agate Field	1-5,000
	Louis A. Chase and Marion Grossman	Danish Wash, Seiber Nose Field	1-5,000
	CC Co.	Cisco	50,000-500,000
	Crest Resources, Inc.	Cisco Springs Field	5,000-50,000
	C.V.S. Oil Exploration	Bar-X Field	50,000-500,000
	Getty Oil Co.	East Canyon Field	50,000-500,000
	Getty Oil Co.	Horse Point Field	50,000-500,000

Table VI-4 Con't

Natural Gas Production and Properties in Utah
(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Thousand Cubic Feet)</u>
Grand (cont.)	Gulf Oil Corp	Book Cliffs Field	No Production
	Buton W. Hancock	Stateline Field	1-5,000
	Ross Jacobs	Cisco Springs Field	50,000-500,000
	RLB Enterprises and Merrion Oil & Gas Corp.	Book Cliffs Field	5,000-50,000
	Rex Monshan	Cisco Dome Filed	5,000-50,000
	Oil Resources, Inc.	Segundo Canyon Field, Moon Ridge Field	1-50,000
	Willard Pease Drilling Co.	Bryson Canyon Field	50,000-500,000
		Pear Park Field, Westwater Field	5,000-50,000
	Polumbus Co.	Moon Ridge Field	5,000-50,000
		Segundo Canyon Field	50,000-500,000
		Westwater Field	500,000 Or More
	Tejas Gas Corp.	Cisco Dome Field	1-5,000
	Tenneco Oil Co.	Cisco Springs Field	1-5,000
	Terra Resources	Bar-X Field	5,000-50,000
	Texaco Inc.	Fence Canyon Field	50,000-500,000
	Isabelle Thomas	Cisco Springs Field	5,000-50,000
	Trend Oil Co.	Bryson Canyon Field	50,000-500,000
	Union Texas Petroleum	Cisco Dome Field	5,000-50,000
	Vukasovich Drilling	Cisco Wash Field	1-5,000
Piute	American Quasar Petroleum	Hogback Ridge Field	No Production

Table VI-4 Con't

Natural Gas Production and Properties in Utah

(1979)

County	Producer	Location of Property	Monthly Production (In Thousand Cubic Feet)
San Juan	Atlantic Richfield Co.	Boundary Butte Field	5,000-50,000
	Aztec Oil & Gas Co.	Gothic Mesa Field	1-5,000
	Consolidated Oil & Gas Inc.	Bluff Field	1-5,000
		Desert Creek Field	5,000-50,000
		Recapture Creek Field	5,000-50,000
	Continental Oil Co.	White Mesa Field	50,000-500,000
	Glenn A. Dow and T. Keith Marks	Recapture Creek	1-5,000
	Walter Duncan Oil Co.	White Mesa Field	5,000-50,000
	Exxon	McElmo Creek Field	50,000-500,000
	Ladd Petroleum Corp.	Recapture Creek Field	1-5,000
	Marathon Oil Co.	Chinle Wash Field	50,000-500,000
	Merrion & Bayless	Bluff Field	5,000-50,000
	Mesa Petroleum Co.	Little Valley	500,000 Or More
	Monsanto Co.	McElmo Mesa Field	5,000-50,000
	Phillips Petroleum Co.	Ratherford Field	500,000 Or More
	Sanchez-O'Brien Petroleum Corp.	Undesignated	1-5,000
	Southland Royalty Co.	Gothic Mesa Field	5,000-50,000
	Superior Oil Co., Anadarko Production Co., Southland Royalties, Continental Oil Co., Moncrief Oil Co., Exxon U.S.A., Texaco Inc., and Wilshire Oil of Tx.	McElmo Creek Unit	500,000 Or More
	Superior Oil Co.	Southeast Field	50,000-500,000
	Texaco Inc.	Greater Aneth Unit Ismay Flodine	500,000 Or More 50,000-500,000
	Union Oil Co.	Big Indian Field Lisbon Field	500,000 Or More 500,000 Or More

Table VI-4 Con't

Natural Gas Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Thousand Cubic Feet)</u>
San Pete	Tenneco Oil Co.	Joe's Valley Field	No Production
Summit	American Quasar Petroleum Co.	Pineview Field	50,000-500,000
	Champlin Petroleum	Pineview Field	500,000 Or More
Uintah	Belco Petroleum Corp.	White River Field	1-5,000
		Stagecoach Field	1-5,000
		Chapita Wells Field	50,000-500,000
	Chevron U.S.A. Inc.	Horseshoe Bend Field	5,000-50,000
		Powder Springs Field	50,000-500,000
		Bluebell Field	1-5,000
		Red Wash Field	500,000 Or More
	CIG Exploration	Bitter Creek Field	5,000-50,000
	Comanche Oil & Gas Co.	Bend, Horseshoe Bend Fields	5,000-50,000
	Consolidated Oil & Gas Co.	Southman Canyon Field	5,000-50,000
	Diamond Shamrock Corp.	Rockhouse Field	50,000-500,000
		Buch Canyon Field	No Production
		Horseshoe Bend Field	5,000-50,000
	Exxon Corp.	Bluebell Field	1-5,000
	Flying Diamond Corp.	Bluebell Field	50,000-500,000
	Gas Producing Enterprises Inc.	Buttes Field	500,000 Or More
	Gulf Oil Corp.	Bluebell Field	500,000 Or More
	Gilman Hill	Natural Buttes	1-5,000
	Hyland Oil Corp.	Horseshoe Bend Field	1-5,000
	Kenneth D. Luff	Horseshoe Bend Field	5,000-50,000
	Mapco Inc	Island Unit Field	50,000-500,000
	Mountain Fuel Supply Co.	Island Unit Field	5,000-50,000

Table VI-4 Con't

Natural Gas Production and Properties in Utah

(1979)

<u>County</u>	<u>Producer</u>	<u>Location of Property</u>	<u>Monthly Production (In Thousand Cubic Feet)</u>
Uintah (cont.)	Pacific Lighting Exploration Co.	Bonanza Field	1-5,000
	Pacific Transmission Supply	Sand Ridge Field	1-5,000
	Powell & Stone	Oil Spings Field	50,000-500,000
	Shell Oil	Bluebell Field	1-5,000
	Sun Oil Co.	Red Wash Field	1-5,000
	Tenneco Oil Co.	Natural Buttes Field	50,000-500,000
	Texaco Inc.	Fence Canyon Field	5,00050,000
		Seep Ridge Field	500,000 Or More
		Walker Hollow Field	50,000-500,000
		Spirit Lake Field	50,000-500,000
	Texas American Oil Corp.	Island Field	50,000-500,000

Source: Carlton H. Stowe, Utah Mineral Industry Operator Directory 1979 (Salt Lake City, Utah: Utah Geological and Mineral Survey, June 1979).

Figure VI-2

Natural Gas Distribution System in Utah

Source: State of Utah, Public Service Commission (Salt Lake City, January 1978).

Footnotes-Section VI

¹Utah Geological and Mineral Survey, January 1, 1980.

SECTION VII

ADVANTAGES OF MINE MOUTH POWER PLANTS IN COMPARISON TO COMBINED CYCLE OR HYBRID POWER PLANTS

Studies of combined cycle facilities or hybrid power plants are relatively few. The few studies that have been conducted have analyzed combined nuclear and fossil-fired energy systems, combined thermal electric production using coal, oil and natural gas, and hybrid geothermal and fossil fuel power plants. (See the annotative bibliography in Appendix I for specific studies.)

Because of the nation's goal to reduce dependence on oil and natural gas as major energy sources, most of the analysis of hybrid power systems has focused on geothermal/coal and coal/nuclear power systems. Little or no analytical work has been performed for combined oil shale and or tar sands/coal or nuclear power systems. This section will primarily focus on the economic and environmental tradeoffs of geothermal/coal power plants. Moreover, from the front-end of the analysis a significant attribute of coal is its status as the least expensive of the fossil fuels. Because oil and gas are more costly, geothermal energy in a hybrid cycle will show even greater savings than the use of coal alone."¹

The following are the conclusions of the study. Site Specific Analysis of Hybrid Geothermal/Fossil Power Plants, conducted for the U.S. Energy Research and Development Administration.

1. A well-designed and sited hybrid power plant can produce electricity at a lower cost than either a conventional coal-fired plant or an all geothermal plant. Several performance characteristics of the hybrid plant account for its economic viability.

2. Geothermal energy could economically contribute more than 20 percent of the total energy consumed in a hybrid plant.
3. The hybrid plant would utilize geothermal energy more efficiently than present concepts for future geothermal plants. For high-quality geothermal resources, the utilization of geothermal energy is about 20 percent greater. For marginal resources, the utilization efficiency can be 1 to 1.5 times twice as great. Thus, the hybrid cycle would be especially useful for marginal geothermal sites located near enough to coal deposits to be economically viable.
4. The thermodynamic efficiency of the coal contribution to electrical power production in a hybrid plant is only slightly less than that of the best all coal-fired plant.

These conclusions were reached notwithstanding two major design restrictions as well as some lesser ones imposed on the hybrid plant used in the analysis. First, the geothermal energy was used only to heat the feedwater before it entered the boiler. Second, the boiler feedwater was heated in a subcritical cycle. Present judgement is that an actual hybrid design would encompass the following features:

1. In addition to feedwater heating, the geothermal energy could have other applications, including: coal drying and beneficiation, air preheating, flue gas reheating, general heating.
2. The water balance in a hybrid plant is such as to allow for complete consumption of the geothermal fluid in evaporative cooling wherever the chemical and local environmental conditions would allow.
3. The restriction to a subcritical cycle holds the steam at just below the critical temperature and pressure. It appears that a supercritical cycle could be utilized, with maximum pressure of about 240 bars (3500 psia).
4. More than one turbine extraction point probably would be used. This allows flexibility to accommodate variations in the geothermal resource, as well as for high temperature steam for auxiliary station equipment. The hybrid plant is designed to accommodate some well shut-downs.

A summary of an economic assessment of nuclear and fossil-fired energy systems which was conducted by the Massachusetts Institute of Technology in 1975 is as follows:

Costs of electricity and thermal energy (380 F° hot water) produced by nuclear and fossil-fired power plants in the 100 MWC size range for 1985 start-up have been estimated (in 1985 dollars, levelized over plant life). While the PWR/Rankine system was estimated to produce electricity as a sole product cheaper than an HTGR/Brayton plant (30.3 versus 41.5 mills/KWhr), the HTGR unit was shown to produce Total Energy products more economically than the PWR (25.2 mills/KWhr and 2.58 \$/MBTU versus 30.3 and 2.93). Break-even fuel costs for comparable fossil-fuel steam-electric power plants were found to be about 16\$/ton for coal and 9\$/bbl for oil. Parametric and sensitivity studies were also carried out to examine the affects of size (50-200 MWC), annual cost of money (8-12%), plant life (20-40 years) and plant startup date (1980-1990). It is concluded that the HTGR/Brayton plant is superior to the other nuclear and fossil/Rankine options for Total Energy applications. The fossil-fired gas turbine/total energy system is identified as a strong competitor for the proposed application and is potentially superior to the HTGR if fossil fuel prices do not escalate prohibitively.³

Footnotes-Section VII

¹City of Burbank, Site-specific analysis of Hybrid Geothermal/Fossil Power Plants, (Prepared for the U.S. Energy Research and Development Administration: June 1977)p. viii.

²Ibid., pp. xiii. and xiv.

³Metcalf, L.J. and Driscoll, M.J., Economic Assessment of Nuclear and Fossil-Fired Energy Systems for DOD Installations (Massachusetts Institute of Technology, Cambridge, Mass.: February 1975).

APPENDIX A

FEDERAL AND STATE OF UTAH REQUIREMENTS

RESOURCE CONSERVATION AND RECOVERY ACT OF 1976

WATER REQUIREMENTS

AIR QUALITY

Public Law 94-580
94th Congress

An Act

To provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials, and to regulate the management of hazardous waste.

Oct. 21
[S. 2]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Resource
Conservation
Recovery
1976.

SHORT TITLE

SECTION 1. This Act may be cited as the "Resource Conservation and Recovery Act of 1976".

42 USC 6
note.

AMENDMENT OF SOLID WASTE DISPOSAL ACT

Sec. 2. The Solid Waste Disposal Act (42 U.S.C. 3251 and following) is amended to read as follows:

"TITLE II—SOLID WASTE DISPOSAL

"Subtitle A—General Provisions

"SHORT TITLE AND TABLE OF CONTENTS

"Sec. 1001. This title (hereinafter in this title referred to as 'this Act'), together with the following table of contents, may be cited as the 'Solid Waste Disposal Act':

42 USC 6
note.

"Subtitle A—General Provisions

- "Sec. 1001. Short title and table of contents.
- "Sec. 1002. Congressional findings.
- "Sec. 1003. Objectives.
- "Sec. 1004. Definitions.
- "Sec. 1005. Governmental cooperation.
- "Sec. 1006. Application of Act and integration with other Acts.
- "Sec. 1007. Financial disclosure.
- "Sec. 1008. Solid waste management information and guidelines.

"Subtitle B—Office of Solid Waste; Authorities of the Administrator

- "Sec. 2001. Office of Solid Waste.
- "Sec. 2002. Authorities of Administrator.
- "Sec. 2003. Resource recovery and conservation panels.
- "Sec. 2004. Grants for discarded tire disposal.
- "Sec. 2005. Annual report.
- "Sec. 2006. General authorization.

"Subtitle C—Hazardous Waste Management

- "Sec. 3001. Identification and listing of hazardous waste.
- "Sec. 3002. Standards applicable to generators of hazardous waste.
- "Sec. 3003. Standards applicable to transporters of hazardous waste.
- "Sec. 3004. Standards applicable to owners and operators of hazardous waste treatment, storage, and disposal facilities.
- "Sec. 3005. Permits for treatment, storage, or disposal of hazardous waste.
- "Sec. 3006. Authorized State hazardous waste programs.
- "Sec. 3007. Inspections.

"Subtitle C--Hazardous Waste Management--Continued

- "Sec. 3008. Federal enforcement.
- "Sec. 3009. Retention of State authority.
- "Sec. 3010. Effective date.
- "Sec. 3011. Authorization of assistance to States.

"Subtitle D--State or Regional Solid Waste Plans

- "Sec. 4001. Objectives of subtitle.
- "Sec. 4002. Federal guidelines for plans.
- "Sec. 4003. Minimum requirements for approval of plans.
- "Sec. 4004. Criteria for sanitary landfills; sanitary landfills required for all disposal.
- "Sec. 4005. Upgrading of open dumps.
- "Sec. 4006. Procedure for development and implementation of State plan.
- "Sec. 4007. Approval of State plan; Federal assistance.
- "Sec. 4008. Federal assistance.
- "Sec. 4009. Rural communities assistance.

"Subtitle E--Duties of the Secretary of Commerce in Resource and Recovery

- "Sec. 5001. Functions.
- "Sec. 5002. Development of specifications for secondary materials.
- "Sec. 5003. Development of markets for recovered materials.
- "Sec. 5004. Technology promotion.

"Subtitle F--Federal Responsibilities

- "Sec. 6001. Application of Federal, State, and local law to Federal facilities.
- "Sec. 6002. Federal procurement.
- "Sec. 6003. Cooperation with Environmental Protection Agency.
- "Sec. 6004. Applicability of solid waste disposal guidelines to executive agencies.

"Subtitle G--Miscellaneous Provisions

- "Sec. 7001. Employee protection.
- "Sec. 7002. Citizen suits.
- "Sec. 7003. Imminent hazard.
- "Sec. 7004. Petition for regulations; public participation.
- "Sec. 7005. Separability.
- "Sec. 7006. Judicial review.
- "Sec. 7007. Grants or contracts for training projects.
- "Sec. 7008. Payments.
- "Sec. 7009. Labor standards.

"Subtitle H--Research, Development, Demonstration, and Information

- "Sec. 8001. Research, demonstrations, training, and other activities.
- "Sec. 8002. Special studies; plans for research, development, and demonstrations.
- "Sec. 8003. Coordination, collection, and dissemination of information.
- "Sec. 8004. Full-scale demonstration facilities.
- "Sec. 8005. Special study and demonstration projects on recovery of useful energy and materials.
- "Sec. 8006. Grants for resource recovery systems and improved solid waste disposal facilities.
- "Sec. 8007. Authorization of appropriations.

"CONGRESSIONAL FINDINGS

"Sec. 1002. (a) SOLID WASTE.—The Congress finds with respect to solid waste—

"(1) that the continuing technological progress and improvement in methods of manufacture, packaging, and marketing of consumer products has resulted in an ever-mounting increase, and in a change in the characteristics, of the mass material discarded by the purchaser of such products;

"(2) that the economic and population growth of our Nation, and the improvements in the standard of living enjoyed by our population, have required increased industrial production to meet

our needs, and have made necessary the demolition of old buildings, the construction of new buildings, and the provision of highways and other avenues of transportation, which, together with related industrial, commercial, and agricultural operations, have resulted in a rising tide of scrap, discarded, and waste materials;

"(3) that the continuing concentration of our population in expanding metropolitan and other urban areas has presented these communities with serious financial, management, intergovernmental, and technical problems in the disposal of solid wastes resulting from the industrial, commercial, domestic, and other activities carried on in such areas;

"(4) that while the collection and disposal of solid wastes should continue to be primarily the function of State, regional, and local agencies, the problems of waste disposal as set forth above have become a matter national in scope and in concern and necessitate Federal action through financial and technical assistance and leadership in the development, demonstration, and application of new and improved methods and processes to reduce the amount of waste and unsalvageable materials and to provide for proper and economical solid-waste disposal practices.

"(b) ENVIRONMENT AND HEALTH.—The Congress finds with respect to the environment and health, that—

"(1) although land is too valuable a national resource to be needlessly polluted by discarded materials, most solid waste is disposed of on land in open dumps and sanitary landfills;

"(2) disposal of solid waste and hazardous waste in or on the land without careful planning and management can present a danger to human health and the environment;

"(3) as a result of the Clean Air Act, the Water Pollution Control Act, and other Federal and State laws respecting public health and the environment, greater amounts of solid waste (in the form of sludge and other pollution treatment residues) have been created. Similarly, inadequate and environmentally unsound practices for the disposal or use of solid waste have created greater amounts of air and water pollution and other problems for the environment and for health;

"(4) open dumping is particularly harmful to health, contaminates drinking water from underground and surface supplies, and pollutes the air and the land;

"(5) hazardous waste presents, in addition to the problems associated with non-hazardous solid waste, special dangers to health and requires a greater degree of regulation than does non-hazardous solid waste; and

"(6) alternatives to existing methods of land disposal must be developed since many of the cities in the United States will be running out of suitable solid waste disposal sites within five years unless immediate action is taken;

"(c) MATERIALS.—The Congress finds with respect to materials, that—

"(1) millions of tons of recoverable material which could be used are needlessly buried each year;

"(2) methods are available to separate usable materials from solid waste; and

"(3) the recovery and conservation of such materials can reduce the dependence of the United States on foreign resources and reduce the deficit in its balance of payments.

42 US
note.
33 US
note.

"(d) **ENERGY.**—The Congress finds with respect to energy, that—

"(1) solid waste represents a potential source of solid fuel, oil, or gas that can be converted into energy;

"(2) the need exists to develop alternative energy sources for public and private consumption in order to reduce our dependence on such sources as petroleum products, natural gas, nuclear and hydroelectric generation; and

"(3) technology exists to produce usable energy from solid waste.

"OBJECTIVES

"Sec. 1003. The objectives of this Act are to promote the protection of health and the environment and to conserve valuable material and energy resources by—

"(1) providing technical and financial assistance to State and local governments and interstate agencies for the development of solid waste management plans (including resource recovery and resource conservation systems) which will promote improved solid waste management techniques (including more effective organizational arrangements), new and improved methods of collection, separation, and recovery of solid waste, and the environmentally safe disposal of nonrecoverable residues;

"(2) providing training grants in occupations involving the design, operation, and maintenance of solid waste disposal systems;

"(3) prohibiting future open dumping on the land and requiring the conversion of existing open dumps to facilities which do not pose a danger to the environment or to health;

"(4) regulating the treatment, storage, transportation, and disposal of hazardous wastes which have adverse effects on health and the environment;

"(5) providing for the promulgation of guidelines for solid waste collection, transport, separation, recovery, and disposal practices and systems;

"(6) promoting a national research and development program for improved solid waste management and resource conservation techniques, more effective organizational arrangements, and new and improved methods of collection, separation, and recovery, and recycling of solid wastes and environmentally safe disposal of nonrecoverable residues;

"(7) promoting the demonstration, construction, and application of solid waste management, resource recovery, and resource conservation systems which preserve and enhance the quality of air, water, and land resources; and

"(8) establishing a cooperative effort among the Federal, State, and local governments and private enterprise in order to recover valuable materials and energy from solid waste.

"DEFINITIONS

"Sec. 1004. As used in this Act:

"(1) The term 'Administrator' means the Administrator of the Environmental Protection Agency.

"(2) The term 'construction,' with respect to any project of construction under this Act, means (A) the erection or building of new structures and acquisition of lands or interests therein, or the acquisition, replacement, expansion, remodeling, alteration, modernization,

or extension of existing structures, and (B) the acquisition and installation of initial equipment of, or required in connection with, new or newly acquired structures or the expanded, remodeled, altered, modernized or extended part of existing structures (including trucks and other motor vehicles, and tractors, cranes, and other machinery) necessary for the proper utilization and operation of the facility after completion of the project; and includes preliminary planning to determine the economic and engineering feasibility and the public health and safety aspects of the project, the engineering, architectural, legal, fiscal, and economic investigations and studies, and any surveys, designs, plans, working drawings, specifications, and other action necessary for the carrying out of the project, and (C) the inspection and supervision of the process of carrying out the project to completion.

"(2A) The term 'demonstration' means the initial exhibition of a new technology process or practice or a significantly new combination or use of technologies, processes or practices, subsequent to the development stage, for the purpose of proving technological feasibility and cost effectiveness.

"(3) The term 'disposal' means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters.

"(4) The term 'Federal agency' means any department, agency, or other instrumentality of the Federal Government, any independent agency or establishment of the Federal Government including any Government corporation, and the Government Printing Office.

"(5) The term 'hazardous waste' means a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may—

"(A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or

"(B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

"(6) The term 'hazardous waste generation' means the act or process of producing hazardous waste.

"(7) The term 'hazardous waste management' means the systematic control of the collection, source separation, storage, transportation, processing, treatment, recovery, and disposal of hazardous wastes.

"(8) For purposes of Federal financial assistance (other than rural communities assistance), the term 'implementation' does not include the acquisition, leasing, construction, or modification of facilities or equipment or the acquisition, leasing, or improvement of land and after December 31, 1970, such term does not include salaries of employees due pursuant to subtitle D of this Act.

"(9) The term 'intermunicipal agency' means an agency established by two or more municipalities with responsibility for planning or administration of solid waste.

"(10) The term 'interstate agency' means an agency of two or more municipalities in different States, or an agency established by two or more States, with authority to provide for the disposal of solid wastes and serving two or more municipalities located in different States.

"(11) The term 'long-term contract' means, when used in relation to solid waste supply, a contract of sufficient duration to assure the

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viability of a resource recovery facility (to the extent that such viability depends upon solid waste supply).

"(12) The term 'manifest' means the form used for identifying the quantity, composition, and the origin, routing, and destination of hazardous waste during its transportation from the point of generation to the point of disposal, treatment, or storage.

"(13) The term 'municipality' (A) means a city, town, borough, county, parish, district, or other public body created by or pursuant to State law, with responsibility for the planning or administration of solid waste management, or an Indian tribe or authorized tribal organization or Alaska Native village or organization, and (B) includes any rural community or unincorporated town or village or any other public entity for which an application for assistance is made by a State or political subdivision thereof.

"(14) The term 'open dump' means a site for the disposal of solid waste which is not a sanitary landfill within the meaning of section 4001.

"(15) The term 'person' means an individual, trust, firm, joint stock company, corporation (including a government corporation), partnership, association, State, municipality, commission, political subdivision of a State, or any interstate body.

"(16) The term 'procurement item' means any device, good, substance, material, product, or other item whether real or personal property which is the subject of any purchase, barter, or other exchange made to procure such item.

"(17) The term 'procuring agency' means any Federal agency, or any State agency or agency of a political subdivision of a State which is using appropriated Federal funds for such procurement, or any person contracting with any such agency with respect to work performed under such contract.

"(18) The term 'recoverable' refers to the capability and likelihood of being recovered from solid waste for a commercial or industrial use.

"(19) The term 'recovered material' means material which has been collected or recovered from solid waste.

"(20) The term 'recovered resources' means material or energy recovered from solid waste.

"(21) The term 'resource conservation' means reduction of the amounts of solid waste that are generated, reduction of overall resource consumption, and utilization of recovered resources.

"(22) The term 'resource recovery' means the recovery of material or energy from solid waste.

"(23) The term 'resource recovery system' means a solid waste management system which provides for collection, separation, recycling, and recovery of solid wastes, including disposal of nonrecoverable waste residues.

"(24) The term 'resource recovery facility' means any facility at which solid waste is processed for the purpose of extracting, converting to energy, or otherwise separating and preparing solid waste for reuse.

416. "(25) The term 'regional authority' means the authority established or designated under section 4006.

"(26) The term 'sanitary landfill' means a facility for the disposal of solid waste which meets the criteria published under section 4001.

"(26.A) The term 'sludge' means any solid, semisolid or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control

facility or any other such waste having similar characteristics and effects.

"(27) The term 'solid waste' means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended (68 Stat. 923).

33 USC 13
42 USC 20
note.

"(28) The term 'solid waste management' means the systematic administration of activities which provide for the collection, source separation, storage, transportation, transfer, processing, treatment, and disposal of solid waste.

"(29) The term 'solid waste management facility' includes (A) any resource recovery system or component thereof, (B) any system, program, or facility for resource conservation, and (C) any facility for the treatment of solid wastes, including hazardous wastes, whether such facility is associated with facilities generating such wastes or otherwise.

"(30) The terms 'solid waste planning', 'solid waste management', and 'comprehensive planning' include planning or management respecting resource recovery and resource conservation.

"(31) The term 'State' means any of the several States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands.

"(32) The term 'State authority' means the agency established or designated under section 4007.

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"(33) The term 'storage', when used in connection with hazardous waste, means the containment of hazardous waste, either on a temporary basis or for a period of years, in such a manner as not to constitute disposal of such hazardous waste.

"(34) The term 'treatment', when used in connection with hazardous waste, means any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or so as to render such waste nonhazardous, safer for transport, amenable for recovery, amenable for storage, or reduced in volume. Such term includes any activity or processing designed to change the physical form or chemical composition of hazardous waste so as to render it nonhazardous.

"(35) The term 'virgin material' means a raw material, including previously unused copper, aluminum, lead, zinc, iron, or other metal or metal ore, any undeveloped resource that is, or with new technology will become, a source of raw materials.

"GOVERNMENTAL COOPERATION

"SEC. 1005. (a) INTERSTATE COOPERATION.—The provisions of this Act to be carried out by States may be carried out by interstate agencies and provisions applicable to States may apply to interstate regions where such agencies and regions have been established by the respective

42 USC 69

States and approved by the Administrator. In any such case, action required to be taken by the Governor of a State, respecting regional designation shall be required to be taken by the Governor of each of the respective States with respect to so much of the interstate region as is within the jurisdiction of that State.

"(b) CONSENT OF CONGRESS TO COMPACTS.—The consent of the Congress is hereby given to two or more States to negotiate and enter into agreements or compacts, not in conflict with any law or treaty of the United States, for—

"(1) cooperative effort and mutual assistance for the management of solid waste or hazardous waste (or both) and the enforcement of their respective laws relating thereto, and

"(2) the establishment of such agencies, joint or otherwise, as they may deem desirable for making effective such agreements or compacts.

No such agreement or compact shall be binding or obligatory upon any State a party thereto unless it is agreed upon by all parties to the agreement and until it has been approved by the Administrator and the Congress.

"APPLICATION OF ACT AND INTEGRATION WITH OTHER ACTS

995.

"SEC. 1006. (a) APPLICATION OF ACT.—Nothing in this Act shall be construed to apply to (or to authorize any State, interstate, or local authority to regulate) any activity or substance which is subject to the Federal Water Pollution Control Act (33 U.S.C. 1151 and following), the Safe Drinking Water Act (42 U.S.C. 300f and following), the Marine Protection, Research and Sanctuaries Act of 1972 (33 U.S.C. 1401 and following), or the Atomic Energy Act of 1954 (42 U.S.C. 2011 and following) except to the extent that such application (or regulation) is not inconsistent with the requirements of such Acts.

"(b) INTEGRATION WITH OTHER ACTS.—The Administrator shall integrate all provisions of this Act for purposes of administration and enforcement and shall avoid duplication, to the maximum extent practicable, with the appropriate provisions of the Clean Air Act (42 U.S.C. 1857 and following), the Federal Water Pollution Control Act (33 U.S.C. 1151 and following), the Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. 135 and following), the Safe Drinking Water Act (42 U.S.C. 300f and following), the Marine Protection, Research and Sanctuaries Act of 1972 (33 U.S.C. 1401 and following) and such other Acts of Congress as grant regulatory authority to the Administrator. Such integration shall be effected only to the extent that it can be done in a manner consistent with the goals and policies expressed in this Act and in the other acts referred to in this subsection.

"FINANCIAL DISCLOSURE

996.

"SEC. 1007. (a) STATEMENT.—Each officer or employee of the Administrator who—

"(1) performs any function or duty under this Act; and

"(2) has any known financial interest in any person who applies for or receives financial assistance under this Act shall, beginning on February 1, 1977, annually file with the Administrator a written statement concerning all such interests held by such officer or employee during the preceding calendar year. Such statement shall be available to the public.

"(b) ACTION BY ADMINISTRATOR.—The Administrator shall—
 "(1) act within ninety days after the date of enactment of this Act—

"(A) to define the term 'known financial interest' for purposes of subsection (a) of this section; and

"(B) to establish the methods by which the requirement to file written statements specified in subsection (a) of this section will be monitored and enforced, including appropriate provision for the filing by such officers and employees of such statements and the review by the Administrator of such statements; and

"(2) report to the Congress on June 1, 1976, and of each succeeding calendar year with respect to such disclosures and the actions taken in regard thereto during the preceding calendar year.

Report to Congress.

"(c) EXEMPTION.—In the rules prescribed under subsection (b) of this section, the Administrator may identify specific positions within the Environmental Protection Agency which are of a nonpolicy-making nature and provide that officers or employees occupying such positions shall be exempt from the requirements of this section.

"(d) PENALTY.—Any officer or employee who is subject to, and knowingly violates, this section shall be fined not more than \$2,500 or imprisoned not more than one year, or both.

"SOLID WASTE MANAGEMENT INFORMATION AND GUIDELINES

"SEC. 1008. (a) GUIDELINES.—Within one year of enactment of this section, and from time to time thereafter, the Administrator shall, in cooperation with appropriate Federal, State, municipal, and intermunicipal agencies, and in consultation with other interested persons, and after public hearings, develop and publish suggested guidelines for solid waste management. Such suggested guidelines shall—

42 USC 6

"(1) provide a technical and economic description of the level of performance that can be attained by various available solid waste management practices (including operating practices) which provide for the protection of public health and the environment;

"(2) not later than two years after the enactment of this section, describe levels of performance, including appropriate methods and degrees of control, that provide at a minimum for (A) protection of public health and welfare; (B) protection of the quality of ground waters and surface waters from leachates; (C) protection of the quality of surface waters from runoff through compliance with effluent limitations under the Federal Water Pollution Control Act, as amended; (D) protection of ambient air quality through compliance with new source performance standards or requirements of air quality implementation plans under the Clean Air Act, as amended; (E) disease and vector control; (F) safety; and (G) esthetics; and

33 USC 1 note.

42 USC 1 note.

"(3) provide minimum criteria to be used by the States to define those solid waste management practices which constitute the open dumping of solid waste or hazardous waste and are to be prohibited under title IV of this Act.

Minimum of management practices.

Where appropriate, such suggested guidelines also shall include minimum information for use in deciding the adequate location, design, and construction of facilities associated with solid waste management

practices, including the consideration of regional, geographic, demographic, and climatic factors.

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"(b) Notice.—The Administrator shall notify the Committee on Public Works of the Senate and the Committee on Interstate and Foreign Commerce of the House of Representatives a reasonable time before publishing any suggested guidelines, pursuant to this section of the content of such proposed suggested guidelines.

**"Subtitle B—Office of Solid Waste; Authorities
of the Administrator**

"OFFICE OF SOLID WASTE

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11.

"Sec. 2001. The Administrator shall establish within the Environmental Protection Agency an Office of Solid Waste (hereinafter referred to as the 'Office') to be headed by a Deputy Assistant Administrator of the Environmental Protection Agency. The duties and responsibilities (other than duties and responsibilities relating to research and development) of the Administrator under this Act (as modified by applicable reorganization plans) shall be carried out through the Office.

"AUTHORITIES OF ADMINISTRATOR

12.

"Sec. 2002. (a) Authorities.—In carrying out this Act, the Administrator is authorized to—

"(1) prescribe, in consultation with Federal, State, and regional authorities, such regulations as are necessary to carry out his functions under this Act;

"(2) consult with or exchange information with other Federal agencies undertaking research, development, demonstration projects, studies, or investigations relating to solid waste;

"(3) provide technical and financial assistance to States or regional agencies in the development and implementation of solid waste plans and hazardous waste management programs;

"(4) consult with representatives of science, industry, agriculture, labor, environmental protection and consumer organizations, and other groups, as he deems advisable; and

"(5) utilize the information, facilities, personnel and other resources of Federal agencies, including the National Bureau of Standards and the National Bureau of the Census, on a reimbursable basis, to perform research and analyses and conduct studies and investigations related to resource recovery and conservation and to otherwise carry out the Administrator's functions under this Act.

"(b) Revision of Regulations.—Each regulation promulgated under this Act shall be reviewed and, where necessary, revised not less frequently than every three years.

"RESOURCE RECOVERY AND CONSERVATION PANELS

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13.

"Sec. 2003. The Administrator shall provide teams of personnel, including Federal, State, and local employees or contractors (hereinafter referred to as 'Resource Conservation and Recovery Panels') to provide States and local governments upon request with technical assistance on solid waste management, resource recovery, and resource conservation. Such teams shall include technical, marketing, financial,

and institutional specialists, and the services of such teams shall be provided without charge to States or local governments.

"GRANTS FOR DISCARDED TIRE DISPOSAL

"Sec. 2004. (a) GRANTS.—The Administrator shall make available grants equal to 5 percent of the purchase price of tire shredders (including portable shredders attached to tire collection trucks) to those eligible applicants best meeting criteria promulgated under this section. An eligible applicant may be any private purchaser, public body, or public-private joint venture. Criteria for receiving grants shall be promulgated under this section and shall include the policy to offer any private purchaser the first option to receive a grant, the policy to develop widespread geographic distribution of tire shredding facilities, the need for such facilities within a geographic area, and the projected risk and viability of any such venture. In the case of an application under this section from a public body, the Administrator shall first make a determination that there are no private purchasers interested in making an application before approving a grant to a public body.

Eligible
applicants
42 USC 6

"(b) AUTHORIZATION.—There is authorized to be appropriated \$750,000 for each of the fiscal years 1978 and 1979 to carry out this section.

"ANNUAL REPORT

"Sec. 2005. The Administrator shall transmit to the Congress and the President, not later than ninety days after the end of each fiscal year, a comprehensive and detailed report on all activities of the Office during the preceding fiscal year. Each such report shall include—

42 USC 6

"(1) a statement of specific and detail objectives for the activities and programs conducted and assisted under this Act;

"(2) statements of the Administrator's conclusions as to the effectiveness of such activities and programs in meeting the stated objectives and the purposes of this Act, measured through the end of such fiscal year;

"(3) a summary of outstanding solid waste problems confronting the Administrator, in order of priority;

"(4) recommendations with respect to such legislation which the Administrator deems necessary or desirable to assist in solving problems respecting solid waste;

"(5) all other information required to be submitted to the Congress pursuant to any other provision of this Act; and

"(6) the Administrator's plans for activities and programs respecting solid waste during the next fiscal year.

"GENERAL AUTHORIZATION

"Sec. 2006. (a) GENERAL ADMINISTRATION.—There are authorized to be appropriated to the Administrator for the purpose of carrying out the provisions of this Act, \$35,000,000 for the fiscal year ending September 30, 1977, \$38,000,000 for the fiscal year ending September 30, 1978, and \$42,000,000 for the fiscal year ending September 30, 1979.

42 USC 6

"(b) RESOURCE RECOVERY AND CONSERVATION PANELS.—Not less than 20 percent of the amount appropriated under subsection (a) shall be used only for purposes of Resource Recovery and Conservation Panels established under section 2003 (including travel expenses incurred by such panels in carrying out their functions under this Act).

"(c) HAZARDOUS WASTE.—Not less than 30 percent of the amount appropriated under subsection (a) shall be used only for purposes of carrying out subtitle C of this Act (relating to hazardous waste) other than section 3011.

"Subtitle C—Hazardous Waste Management

"IDENTIFICATION AND LISTING OF HAZARDOUS WASTE

921. "SEC. 3001. (a) CRITERIA FOR IDENTIFICATION OR LISTING.—Not later than eighteen months after the date of the enactment of this Act, the Administrator shall, after notice and opportunity for public hearing, and after consultation with appropriate Federal and State agencies, develop and promulgate criteria for identifying the characteristics of hazardous waste, and for listing hazardous waste, which should be subject to the provisions of this subtitle, taking into account toxicity, persistence, and degradability in nature, potential for accumulation in tissue, and other related factors such as flammability, corrosiveness, and other hazardous characteristics. Such criteria shall be revised from time to time as may be appropriate.

799. "79. (b) IDENTIFICATION AND LISTING.—Not later than eighteen months after the date of enactment of this section, and after notice and opportunity for public hearing, the Administrator shall promulgate regulations identifying the characteristics of hazardous waste, and listing particular hazardous wastes (within the meaning of section 1004(5)), which shall be subject to the provisions of this subtitle. Such regulations shall be based on the criteria promulgated under subsection (a) and shall be revised from time to time thereafter as may be appropriate.

"(c) PETITION BY STATE GOVERNOR.—At any time after the date eighteen months after the enactment of this title, the Governor of any State may petition the Administrator to identify or list a material as a hazardous waste. The Administrator shall act upon such petition within ninety days following his receipt thereof and shall notify the Governor of such action. If the Administrator denies such petition because of financial considerations, in providing such notice to the Governor he shall include a statement concerning such considerations.

"STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE

922. "18. "22. "SEC. 3002. Not later than eighteen months after the date of the enactment of this section, and after notice and opportunity for public hearings and after consultation with appropriate Federal and State agencies, the Administrator shall promulgate regulations establishing such standards, applicable to generators of hazardous waste identified or listed under this subtitle, as may be necessary to protect human health and the environment. Such standards shall establish requirements respecting—

"(1) recordkeeping practices that accurately identify the quantities of such hazardous waste generated, the constituents thereof which are significant in quantity or in potential harm to human health or the environment, and the disposition of such wastes;

"(2) labeling practices for any containers used for the storage, transport, or disposal of such hazardous waste such as will identify accurately such waste;

"(3) use of appropriate containers for such hazardous waste;

"(4) furnishing of information on the general chemical compo-

stration, except as otherwise specifically provided in section 8004(d), the Administrator may make grants to or enter into contracts (including contracts for construction) with, public agencies and authorities or private persons.

"(2) Contracts for research, development, or demonstrations or for both (including contracts for construction) shall be made in accordance with and subject to the limitations provided with respect to research contracts of the military departments in title 10, United States Code, section 2353, except that the determination, approval, and certification required thereby shall be made by the Administrator.

"(3) Any invention made or conceived in the course of, or under, any contract under this Act shall be subject to section 9 of the Federal Nonnuclear Energy Research and Development Act of 1974 to the same extent and in the same manner as inventions made or conceived in the course of contracts under such Act, except that in applying such section, the Environmental Protection Agency shall be substituted for the Energy Research and Development Administration and the words 'solid waste' shall be substituted for the word 'energy' where appropriate.

"(4) For carrying out the purpose of this Act the Administrator may detail personnel of the Environmental Protection Agency to agencies eligible for assistance under this section.

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**"SPECIAL STUDIES; PLANS FOR RESEARCH, DEVELOPMENT, AND
DEMONSTRATIONS**

"SEC. 8002. (a) GLASS AND PLASTIC.—The Administrator shall undertake a study and publish a report on resource recovery from glass and plastic waste, including a scientific, technological, and economic investigation of potential solutions to implement such recovery.

42 USC

"(b) COMPOSITION OF WASTE STREAM.—The Administrator shall undertake a systematic study of the composition of the solid waste stream and of anticipated future changes in the composition of such stream and shall publish a report containing the results of such study and quantitatively evaluating the potential utility of such components.

"(c) PRIORITIES STUDY.—For purposes of determining priorities for research on recovery of materials and energy from solid waste and developing materials and energy recovery research, development, and demonstration strategies, the Administrator shall review, and make a study of, the various existing and promising techniques of energy recovery from solid waste (including, but not limited to, waterwall furnace incinerators, dry shredded fuel systems, pyrolysis, densified refuse-derived fuel systems, anaerobic digestion, and fuel and feedstock preparation systems). In carrying out such study the Administrator shall investigate with respect to each such technique—

"(1) the degree of public need for the potential results of such research, development, or demonstration,

"(2) the potential for research, development, and demonstration without Federal action, including the degree of restraint on such potential posed by the risks involved, and

"(3) the magnitude of effort and period of time necessary to develop the technology to the point where Federal assistance can be ended.

"(d) SMALL-SCALE AND LOW TECHNOLOGY STUDY.—The Administrator shall undertake a comprehensive study and analysis of, and publish a report on, systems of small-scale and low technology solid

listed under this subtitle, as may be necessary to protect human health and the environment. Such standards shall include, but need not be limited to, requirements respecting—

"(1) maintaining records of all hazardous wastes identified or listed under this title which is treated, stored, or disposed of, as the case may be, and the manner in which such wastes were treated, stored, or disposed of;

"(2) satisfactory reporting, monitoring, and inspection and compliance with the manifest system referred to in section 3002(5);

"(3) treatment, storage, or disposal of all such waste received by the facility pursuant to such operating methods, techniques, and practices as may be satisfactory to the Administrator;

"(4) the location, design, and construction of such hazardous waste treatment, disposal, or storage facilities;

"(5) contingency plans for effective action to minimize unanticipated damage from any treatment, storage, or disposal of any such hazardous waste;

"(6) the maintenance of operation of such facilities and requiring such additional qualifications as to ownership, continuity of operation, training for personnel; and financial responsibility as may be necessary or desirable; and

"(7) compliance with the requirements of section 3005 respecting permits for treatment, storage, or disposal.

No private entity shall be precluded by reason of criteria established under paragraph (6) from the ownership or operation of facilities providing hazardous waste treatment, storage, or disposal services where such entity can provide assurances of financial responsibility and continuity of operation consistent with the degree and duration of risks associated with the treatment, storage, or disposal of specified hazardous waste.

"PERMITS FOR TREATMENT, STORAGE, OR DISPOSAL OF HAZARDOUS WASTE

5. "SEC. 3005. (a) PERMIT REQUIREMENTS.—Not later than eighteen months after the date of the enactment of this section, the Administrator shall promulgate regulations requiring each person owning or operating a facility for the treatment, storage, or disposal of hazardous waste identified or listed under this subtitle to have a permit issued pursuant to this section. Such regulations shall take effect on the date provided in section 3010 and upon and after such date the disposal of any such hazardous waste is prohibited except in accordance with such a permit.

"(b) REQUIREMENTS OF PERMIT APPLICATION.—Each application for a permit under this section shall contain such information as may be required under regulations promulgated by the Administrator, including information respecting—

"(1) estimates with respect to the composition, quantities, and concentrations of any hazardous waste identified or listed under this subtitle, or combinations of any such hazardous waste and any other solid waste, proposed to be disposed of, treated, transported, or stored, and the time, frequency, or rate of which such waste is proposed to be disposed of, treated, transported, or stored; and

"(2) the site at which such hazardous waste or the products of treatment of such hazardous waste will be disposed of, treated, transported to, or stored.

“(e) **PERMIT ISSUANCE.**—Upon a determination by the Administrator (or a State, if applicable), of compliance by a facility for which a permit is applied for under this section with the requirements of this section and section 3004, the Administrator (or the State) shall issue a permit for such facilities. In the event permit applicants propose modification of their facilities, or in the event the Administrator (or the State) determines that modifications are necessary to conform to the requirements under this section and section 3004, the permit shall specify the time allowed to complete the modifications.

“(d) **PERMIT REVOCATION.**—Upon a determination by the Administrator (or by a State, in the case of a State having an authorized hazardous waste program under section 3006) of noncompliance by a facility having a permit under this title with the requirements of this section or section 3004, the Administrator (or State, in the case of a State having an authorized hazardous waste program under section 3006) shall revoke such permit.

“(e) **INTERIM STATUS.**—Any person who—

“(1) owns or operates a facility required to have a permit under this section which facility is in existence on the date of enactment of this Act,

“(2) has complied with the requirements of section 3010(a), and

“(3) has made an application for a permit under this section shall be treated as having been issued such permit until such time as final administrative disposition of such application is made, unless the Administrator or other plaintiff proves that final administrative disposition of such application has not been made because of the failure of the applicant to furnish information reasonably required or requested in order to process the application.

“AUTHORIZED STATE HAZARDOUS WASTE PROGRAMS

“Sec. 3006. (a) **FEDERAL GUIDELINES.**—Not later than eighteen months after the date of enactment of this Act, the Administrator, after consultation with State authorities, shall promulgate guidelines to assist States in the development of State hazardous waste programs. 42 US

“(b) **AUTHORIZATION OF STATE PROGRAM.**—Any State which seeks to administer and enforce a hazardous waste program pursuant to this subtitle may develop and, after notice and opportunity for public hearing, submit to the Administrator an application, in such form as he shall require, for authorization of such program. Within ninety days following submission of an application under this subsection, the Administrator shall issue a notice as to whether or not he expects such program to be authorized, and within ninety days following such notice (and after opportunity for public hearing) he shall publish his findings as to whether or not the conditions listed in items (1), (2), and (3) below have been met. Such State is authorized to carry out such program in lieu of the Federal program under this subtitle in such State and to issue and enforce permits for the storage, treatment, or disposal of hazardous waste unless, within ninety days following submission of the application the Administrator notifies such State that such program may not be authorized and, within ninety days following such notice and after opportunity for public hearing, he finds that (1) such State program is not equivalent to the Federal program under this subtitle, (2) such program is not consistent with the Federal or State programs applicable in other States, or (3) such

program does not provide adequate enforcement of compliance with the requirements of this subtitle.

"(c) **INTERIM AUTHORIZATION.**—Any State which has in existence a hazardous waste program pursuant to State law before the date ninety days after the date required for promulgation of regulations under sections 3002, 3003, 3004, and 3005, submit to the Administrator evidence of such existing program and may request a temporary authorization to carry out such program under this subtitle. The Administrator shall, if the evidence submitted shows the existing State program to be substantially equivalent to the Federal program under this subtitle, grant an interim authorization to the State to carry out such program in lieu of the Federal program pursuant to this subtitle for a twenty-four month period beginning on the date six months after the date required for promulgation of regulations under sections 3002 through 3005.

"(d) **EFFECT OF STATE PERMIT.**—Any action taken by a State under a hazardous waste program authorized under this section shall have the same force and effect as action taken by the Administrator under this subtitle.

"(e) **WITHDRAWAL OF AUTHORIZATION.**—Whenever the Administrator determines after public hearing that a State is not administering and enforcing a program authorized under this section in accordance with requirements of this section, he shall so notify the State and, if appropriate corrective action is not taken within a reasonable time, not to exceed ninety days, the Administrator shall withdraw authorization of such program and establish a Federal program pursuant to this subtitle. The Administrator shall not withdraw authorization of any such program unless he shall first have notified the State, and made public, in writing, the reasons for such withdrawal.

"INSPECTIONS

27. "SEC. 3007. (a) **ACCESS ENTRY.**—For purposes of developing or assisting in the development of any regulation or enforcing the provisions of this subtitle, any person who generates, stores, treats, transports, disposes of, or otherwise handles hazardous wastes shall, upon request of any officer or employee of the Environmental Protection Agency, duly designated by the Administrator, or upon request of any duly designated officer employee of a State having an authorized hazardous waste program, furnish or permit such person at all reasonable times to have access to, and to copy all records relating to such wastes. For the purposes of developing or assisting in the development of any regulation or enforcing the provisions of this title, such officers or employees are authorized—

"(1) to enter at reasonable times any establishment or other place maintained by any person where hazardous wastes are generated, stored, treated, or disposed of;

"(2) to inspect and obtain samples from any person of any such wastes and samples of any containers or labeling for such wastes. Each such inspection shall be commenced and completed with reasonable promptness. If the officer or employee obtains any samples, prior to leaving the premises, he shall give to the owner, operator, or agent in charge a receipt describing the sample obtained and if requested a portion of each such sample equal in volume or weight to the portion retained. If any analysis is made of such samples, a copy of the results

of such analysis shall be furnished promptly to the owner, operator, or agent in charge.

"(b) **AVAILABILITY TO PUBLIC.**—Any records, reports, or information obtained from any person under this section shall be available to the public, except that upon a showing satisfactory to the Administrator (or the State, as the case may be) by any person that records, reports, or information, or particular part thereof, to which the Administrator (or the State, as the case may be) has access under this section if made public, would divulge information entitled to protection under section 1905 of title 18 of the United States Code, the Administrator (or the State, as the case may be) shall consider such information or particular portion thereof confidential in accordance with the purposes of that section, except that such record, report, document, or information may be disclosed to other officers, employees, or authorized representatives of the United States concerned with carrying out this Act, or when relevant in any proceeding under this Act.

"FEDERAL ENFORCEMENT

"**SEC. 3008. (a) COMPLIANCE ORDERS.**—(1) Except as provided in paragraph (2), whenever on the basis of any information the Administrator determines that any person is in violation of any requirement of this subtitle, the Administrator shall give notice to the violator of his failure to comply with such requirement. If such violation extends beyond the thirtieth day after the Administrator's notification, the Administrator may issue an order requiring compliance within a specified time period or the Administrator may commence a civil action in the United States district court in the district in which the violation occurred for appropriate relief, including a temporary or permanent injunction. 42 USC

"(2) In the case of a violation of any requirement of this subtitle where such violation occurs in a State which is authorized to carry out a hazardous waste program under section 3006, the Administrator shall give notice to the State in which such violation has occurred thirty days prior to issuing an order or commencing a civil action under this section.

"(3) If such violator fails to take corrective action within the time specified in the order, he shall be liable for a civil penalty of not more than \$25,000 for each day of continued noncompliance and the Administrator may suspend or revoke any permit issued to the violator (whether issued by the Administrator or the State). Penalty

"(b) **PUBLIC HEARING.**—Any order or any suspension or revocation of a permit shall become final unless, no later than thirty days after the order or notice of the suspension or revocation is served, the person or persons named therein request a public hearing. Upon such request the Administrator shall promptly conduct a public hearing. In connection with any proceeding under this section the Administrator may issue subpoenas for the attendance and testimony of witnesses and the production of relevant papers, books, and documents, and may promulgate rules for discovery procedures. Subpen

"(c) **REQUIREMENTS OF COMPLIANCE ORDERS.**—Any order issued under this section shall state with reasonable specificity the nature of the violation and specify a time for compliance and assess a penalty, if any, which the Administrator determines is reasonable taking into account the seriousness of the violation and any good faith efforts to comply with the applicable requirements. Penalty

"(d) CRIMINAL PENALTY.—Any person who knowingly—

"(1) transports any hazardous waste listed under this subtitle to a facility which does not have a permit under section 3005 (or 3006 in the case of a State program),

"(2) disposes of any hazardous waste listed under this subtitle without having obtained a permit therefor under this subtitle,

"(3) makes any false statement or representation in any application, label, manifest, record, report, permit or other document filed, maintained, or used for purposes of compliance with this subtitle.

shall, upon conviction, be subject to a fine of not more than \$25,000 for each day of violation, or to imprisonment not to exceed one year, or both. If the conviction is for a violation committed after a first conviction of such person under this paragraph, punishment shall be by a fine of not more than \$50,000 per day of violation, or by imprisonment for not more than two years, or by both.

"RETENTION OF STATE AUTHORITY

2. **"Sec. 3009. Upon the effective date of regulations under this subtitle no State or political subdivision may impose any requirements less stringent than those authorized under this subtitle respecting the same matter as governed by such regulations, except that if application of a regulation with respect to any matter under this subtitle is postponed or enjoined by the action of any court, no State or political subdivision shall be prohibited from acting with respect to the same aspect of such matter until such time as such regulation takes effect.**

"EFFECTIVE DATE

0. **"Sec. 3010. (a) PRELIMINARY NOTIFICATION.—Not later than ninety days after promulgation or revision of regulations under section 3001 identifying by its characteristics or listing any substance as hazardous waste subject to this subtitle, any person generating or transporting such substance or owning or operating a facility for treatment, storage, or disposal of such substance shall file with the Administrator (or with States having authorized hazardous waste permit programs under section 3006) a notification stating the location and general description of such activity and the identified or listed hazardous wastes handled by such person. Not more than one such notification shall be required to be filed with respect to the same substance. No identified or listed hazardous waste subject to this subtitle may be transported, treated, stored, or disposed of unless notification has been given as required under this subsection.**

"(b) EFFECTIVE DATE OF REGULATION.—The regulations under this subtitle respecting requirements applicable to the generation, transportation, treatment, storage, or disposal of hazardous waste (including requirements respecting permits for such treatment, storage, or disposal) shall take effect on the date six months after the date of promulgation thereof (or six months after the date of revision in the case of any regulation which is revised after the date required for promulgation thereof).

"AUTHORIZATION OF ASSISTANCE TO STATES

1. **Sec. 3011. (a) AUTHORIZATION.—There is authorized to be appropriated \$25,000,000 for each of the fiscal years 1978 and 1979 to be used to**

make grants to the States for purposes of assisting the States in the development and implementation of authorized State hazardous waste programs.

"(b) **ALLOCATION.**—Amounts authorized to be appropriated under subsection (a) shall be allocated among the States on the basis of regulations promulgated by the Administrator, after consultation with the States, which take into account, the extent to which hazardous waste is generated, transported, treated, stored, and disposed of within such State, the extent of exposure of human beings and the environment within such State to such waste, and such other factors as the Administrator deems appropriate.

"Subtitle D—State or Regional Solid Waste Plans

"OBJECTIVES OF SUBTITLE

"Sec. 4001. The objectives of this subtitle are to assist in developing and encouraging methods for the disposal of solid waste which are environmentally sound and which maximize the utilization of valuable resources and to encourage resource conservation. Such objectives are to be accomplished through Federal technical and financial assistance to States or regional authorities for comprehensive planning pursuant to Federal guidelines designed to foster cooperation among Federal, State, and local governments and private industry. 42 USC

"FEDERAL GUIDELINES FOR PLANS

"Sec. 4002. (a) **GUIDELINES FOR IDENTIFICATION OF REGIONS.**—For purposes of encouraging and facilitating the development of regional planning for solid waste management, the Administrator, within one hundred and eighty days after the date of enactment of this section and after consultation with appropriate Federal, State, and local authorities, shall by regulation publish guidelines for the identification of those areas which have common solid waste management problems and are appropriate units for planning regional solid waste management services. Such guidelines shall consider— Publication 42 USC

"(1) the size and location of areas which should be included,

"(2) the volume of solid waste which should be included, and

"(3) the available means of coordinating regional planning with other related regional planning and for coordination of such regional planning into the State plan.

"(b) **GUIDELINES FOR STATE PLANS.**—Not later than eighteen months after the date of enactment of this section and after notice and hearing, the Administrator shall, after consultation with appropriate Federal, State, and local authorities, promulgate regulations containing guidelines to assist in the development and implementation of State solid waste management plans (hereinafter in this title referred to as 'State plans'). The guidelines shall contain methods for achieving the objectives specified in section 4001. Such guidelines shall be reviewed from time to time, but not less frequently than every three years, and revised as may be appropriate. Regulation

"(c) **CONSIDERATIONS FOR STATE PLAN GUIDELINES.**—The guidelines promulgated under subsection (b) shall consider— Review.

"(1) the varying regional, geologic, hydrologic, climatic, and other circumstances under which different solid waste practices are required in order to insure the reasonable protection of the quality

the reasonable protection of the quality of the surface waters from surface runoff contamination, and the reasonable protection of ambient air quality;

"(2) characteristics and conditions of collection, storage, processing, and disposal operating methods, techniques and practices, and location of facilities where such operating methods, techniques, and practices are conducted, taking into account the nature of the material to be disposed;

"(3) methods for closing or upgrading open dumps for purposes of eliminating potential health hazards;

"(4) population density, distribution, and projected growth;

"(5) geographic, geologic, climatic, and hydrologic characteristics;

"(6) the type and location of transportation;

"(7) the profile of industries;

"(8) the constituents and generation rates of waste;

"(9) the political, economic, organizational, financial, and management problems affecting comprehensive solid waste management;

"(10) types of resource recovery facilities and resource conservation systems which are appropriate; and

"(11) available new and additional markets for recovered material.

"MINIMUM REQUIREMENTS FOR APPROVAL OF PLANS

3. "SEC. 4003. In order to be approved under section 4007, each State plan must comply with the following minimum requirements—

"(1) The plan shall identify (in accordance with section 4006(b)) (A) the responsibilities of State, local, and regional authorities in the implementation of the State plan, (B) the distribution of Federal funds to the authorities responsible for development and implementation of the State plan, and (C) the means for coordinating regional planning and implementation under the State plan.

"(2) The plan shall, in accordance with section 4005(c), prohibit the establishment of new open dumps within the State, and contain requirements that all solid waste (including solid waste originating in other States, but not including hazardous waste) shall be (A) utilized for resource recovery or (B) disposed of in sanitary landfills (within the meaning of section 4004(a)) or otherwise disposed of in an environmentally sound manner.

"(3) The plan shall provide for the closing or upgrading of all existing open dumps within the State pursuant to the requirements of section 4005.

"(4) The plan shall provide for the establishment of such State regulatory powers as may be necessary to implement the plan.

"(5) The plan shall provide that no local government within the State shall be prohibited under State or local law from entering into long-term contracts for the supply of solid waste to resource recovery facilities.

"(6) The plan shall provide for such resource conservation or recovery and for the disposal of solid waste in sanitary landfills or any combination of practices so as may be necessary to use or dispose of such waste in a manner that is environmentally sound.

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"CRITERIA FOR SANITARY LANDFILLS; SANITARY LANDFILLS REQUIRED FOR ALL DISPOSAL.

"SEC. 4001. (a) CRITERIA FOR SANITARY LANDFILLS.—Not later than one year after the date of enactment of this section, after consultation with the States, and after notice and public hearings, the Administrator shall promulgate regulations containing criteria for determining which facilities shall be classified as sanitary landfills and which shall be classified as open dumps within the meaning of this Act. At a minimum, such criteria shall provide that a facility may be classified as a sanitary landfill and not an open dump only if there is no reasonable probability of adverse effects on health or the environment from disposal of solid waste at such facility. Such regulations may provide for the classification of the types of sanitary landfills. 42 USC

"(b) DISPOSAL REQUIRED TO BE IN SANITARY LANDFILLS, ETC.—For purposes of complying with section 4003(2) each State plan shall prohibit the establishment of open dumps and contain a requirement that disposal of all solid waste within the State shall be in compliance with such section 4003(2).

"(c) EFFECTIVE DATE.—The prohibition contained in subsection (b) shall take effect on the date six months after the date of promulgation of regulations under subsection (a) or on the date of approval of the State plan, whichever is later.

"UPGRADING OF OPEN DUMPS

"SEC. 4005. (a) OPEN DUMPS.—For purposes of this Act, the term 'open dump' means any facility or site where solid waste is disposed of which is not a sanitary landfill which meets the criteria promulgated under section 4004 and which is not a facility for disposal of hazardous waste. 42 USC

"(b) INVENTORY.—Not later than one year after promulgation of regulations under section 4004, the Administrator, with the cooperation of the Bureau of the Census shall publish an inventory of all disposal facilities or sites in the United States which are open dumps within the meaning of this Act.

"(c) CLOSING OR UPGRADING OF EXISTING OPEN DUMPS.—Any solid waste management practice or disposal of solid waste or hazardous waste which constitutes the open dumping of solid waste or hazardous waste is prohibited, except in the case of any practice or disposal of solid waste under a timetable or schedule for compliance established under this section. For purposes of complying with section 4003(2), each State plan shall contain a requirement that all existing disposal facilities or sites for solid waste in such State which are open dumps listed in the inventory under subsection (b) shall comply with such measures as may be promulgated by the Administrator to eliminate health hazards and minimize potential health hazards. Each such plan shall establish, for any entity which demonstrates that it has considered other public or private alternatives for solid waste management to comply with the prohibition on open dumping and is unable to utilize such alternatives to so comply, a timetable or schedule for compliance for such practice or disposal of solid waste which specifies a schedule of remedial measures, including an enforceable sequence of actions or operations, leading to compliance with the prohibition on open dumping of solid waste within a reasonable time (not to exceed 5 years from the date of publication of the inventory under subsection (b)).

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"PROCEDURE FOR DEVELOPMENT AND IMPLEMENTATION OF STATE PLAN

16. "SEC. 4006. (a) IDENTIFICATION OF REGIONS.—Within one hundred and eighty days after publication of guidelines under section 4002(a) (relating to identification of regions), the Governor of each State, after consultation with local elected officials, shall promulgate regulations based on such guidelines identifying the boundaries of each area within the State which, as a result of urban concentrations, geographic conditions, markets, and other factors, is appropriate for carrying out regional solid waste management. Such regulations may be modified from time to time (identifying additional or different regions) pursuant to such guidelines.

- "(b) IDENTIFICATION OF STATE AND LOCAL AGENCIES AND RESPONSIBILITIES.—(1) Within one hundred and eighty days after the Governor promulgates regulations under subsection (a), for purposes of facilitating the development and implementation of a State plan which will meet the minimum requirements of section 4003, the State, together with appropriate elected officials of general purpose units of local government, shall jointly (A) identify an agency to develop the State plan and identify one or more agencies to implement such plan, and (B) identify which solid waste functions will, under such State plan, be planned for and carried out by the State and which such functions will, under such State plan, be planned for and carried out by a regional or local authority or a combination of regional or local and State authorities. If a multi-functional regional agency authorized by State law to conduct solid waste planning and management (the members of which are appointed by the Governor) is in existence on the date of enactment of this Act, the Governor shall identify such authority for purposes of carrying out within such region clause (A) of this paragraph. Where feasible, designation of the agency for the affected area designated under section 208 of the Federal Water Pollution Control Act (86 Stat. 839) shall be considered. A State agency identified under this paragraph shall be established or designated by the Governor of such State. Local or regional agencies identified under this paragraph shall be composed of individuals at least a majority of whom are elected local officials.
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"(2) If planning and implementation agencies are not identified and designated as required under paragraph (1) for any affected area, the governor shall, before the date two hundred and seventy days after promulgation of regulations under subsection (a), establish or designate a State agency to develop and implement the State plan for such area.

"(c) INTERSTATE REGIONS.—(1) In the case of any region which, pursuant to the guidelines published by the Administrator under section 4002(a) (relating to identification of regions), would be located in two or more States, the Governors of the respective States, after consultation with local elected officials, shall consult, cooperate, and enter into agreements identifying the boundaries of such region pursuant to subsection (a).

"(2) Within one hundred and eighty days after an interstate region is identified by agreement under paragraph (1), appropriate elected officials of general purpose units of local government within such region shall jointly establish or designate an agency to develop a plan for such region. If no such agency is established or designated within such period by such officials, the Governors of the respective States may, by agreement, establish or designate for such purpose a single

representative organization including elected officials of general purpose units of local government within such region.

"(3) Implementation of interstate regional solid waste management plans shall be conducted by units of local government for any portion of a region within their jurisdiction, or by multijurisdictional agencies or authorities designated in accordance with State law, including those designated by agreement by such units of local government for such purpose. If no such unit, agency, or authority is so designated, the respective Governors shall designate or establish a single interstate agency to implement such plan.

"(4) For purposes of this subtitle, so much of an interstate regional plan as is carried out within a particular State shall be deemed part of the State plan for such State.

"APPROVAL OF STATE PLAN; FEDERAL ASSISTANCE

"SEC. 4007. (a) PLAN APPROVAL.—The Administrator shall, within six months after a State plan has been submitted for approval, approve or disapprove the plan. The Administrator shall approve a plan if he determines that—

"(1) it meets the requirements of paragraphs (1), (2), (3), and (5) of section 4003; and

"(2) it contains provision for revision of such plan, after notice and public hearing, whenever the Administrator, by regulation, determines—

"(A) that revised regulations respecting minimum requirements have been promulgated under paragraphs (1), (2), (3), and (5) of section 4003 with which the State plan is not in compliance;

"(B) that information has become available which demonstrates the inadequacy of the plan to effectuate the purposes of this subtitle; or

"(C) that such revision is otherwise necessary.

The Administrator shall review approved plans from time to time and if he determines that revision or corrections are necessary to bring such plan into compliance with the minimum requirements promulgated under section 4003 (including new or revised requirements), he shall, after notice and opportunity for public hearing, withdraw his approval of such plan. Such withdrawal of approval shall cease to be effective upon the Administrator's determination that such complies with such minimum requirements.

"(b) ELIGIBILITY OF STATES FOR FEDERAL FINANCIAL ASSISTANCE.—

(1) The Administrator shall approve a State application for financial assistance under this subtitle, and make grants to such State, if such State and local and regional authorities within such State have complied with the requirements of section 4006 within the period required under such section and if such State has a State plan which has been approved by the Administrator under this subtitle.

"(2) The Administrator shall approve a State application for financial assistance under this subtitle, and make grants to such State, for fiscal years 1978 and 1979 if the Administrator determines that the State plan continues to be eligible for approval under subsection (a) and is being implemented by the State.

"(3) Upon withdrawal of approval of a State plan under subsection (a), the Administrator shall withhold Federal financial and technical assistance under this subtitle (other than such technical assistance as

may be necessary to assist in obtaining the reinstatement of approval) until such time as such approval is reinstated.

"(C) **EXISTING ACTIVITIES.**—Nothing in this subtitle shall be construed to prevent or affect any activities respecting solid waste planning or management which are carried out by State, regional, or local authorities unless such activities are inconsistent with a State plan approved by the Administrator under this subtitle.

"FEDERAL ASSISTANCE

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"SEC. 4008. (a) AUTHORIZATION OF FEDERAL FINANCIAL ASSISTANCE.—(1) There are authorized to be appropriated \$30,000,000 for fiscal year 1978 and \$10,000,000 for fiscal year 1979 for purposes of making grants to the States for the development and implementation of State plans under this subtitle.

"(2) (A) The Administrator is authorized to provide financial assistance to States, counties, municipalities, and intermunicipal agencies and State and local public solid waste management authorities for implementation of programs to provide solid waste management, resource recovery, and resource conservation services and hazardous waste management. Such assistance shall include assistance for facility planning and feasibility studies; expert consultation; surveys and analyses of market needs; marketing of recovered resources; technology assessments; legal expenses; construction feasibility studies; source separation projects; and fiscal or economic investigations or studies; but such assistance shall not include any other element of construction, or any acquisition of land or interest in land, or any subsidy for the price of recovered resources. Agencies assisted under this subsection shall consider existing solid waste management and hazardous waste management services and facilities as well as facilities proposed for construction.

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"(B) An applicant for financial assistance under this paragraph must agree to comply with respect to the project or program assisted with the applicable requirements of section 4005 and Subtitle C of this Act and apply applicable solid waste management practices, methods, and levels of control consistent with any guidelines published pursuant to section 1003 of this Act. Assistance under this paragraph shall be available only for programs certified by the State to be consistent with any applicable State or areawide solid waste management plan or program.

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"(C) There are authorized to be appropriated \$15,000,000 for each of the fiscal years 1978 and 1979 for purposes of this section.

"(b) **STATE ALLOTMENT.**—The sums appropriated in any fiscal year under subsection (a) (1) shall be allotted by the Administrator among all States, in the ratio that the population in each State bears to the population in all of the States, except that no State shall receive less than one-half of 1 per centum of the sums so allotted in any fiscal year. No State shall receive any grant under this section during any fiscal year when its expenditures of non-Federal funds for other than non-recurrent expenditures for solid waste management control programs will be less than its expenditures were for such programs during fiscal year 1975, except that such funds may be reduced by an amount equal to their proportionate share of any general reduction of State spending ordered by the Governor or legislature of such State. No State shall receive any grant for solid waste management programs unless

the Administrator is satisfied that such grant will be so used as to supplement and, to the extent practicable, increase the level of State, local, regional, or other non-Federal funds that would in the absence of such grant be made available for the maintenance of such programs.

"(c) **DISTRIBUTION OF FEDERAL FINANCIAL ASSISTANCE WITHIN THE STATE.**—The Federal assistance allotted to the States under subsection (b) shall be allocated by the State receiving such funds to State, local, regional, and interstate authorities carrying out planning and implementation of the State plan. Such allocation shall be based upon the responsibilities of the respective parties as determined pursuant to section 4006(b).

"(d) **TECHNICAL ASSISTANCE.**—The Administrator may provide technical assistance to State and local governments for purposes of developing and implementing State plans. Technical assistance respecting resource recovery and conservation may be provided through resource recovery and conservation panels, established in the Environmental Protection Agency under subtitle B, to assist the State and local governments with respect to particular resource recovery and conservation projects under consideration and to evaluate their effect on the State plan.

"(e) **SPECIAL COMMUNITIES.**—(1) The Administrator, in cooperation with State and local officials, shall identify communities within the United States (A) having a population of less than twenty-five thousand persons, (B) having solid waste disposal facilities in which more than 75 per centum of the solid waste disposal of is from areas outside the jurisdiction of the communities, and (C) which have serious environmental problems resulting from the disposal of such solid waste.

"(2) There is authorized to be appropriated to the Administrator \$2,500,000 for each of the fiscal years 1978 and 1979 to make grants to be used for the conversion, improvement, or consolidation of existing solid waste disposal facilities, or for the construction of new solid waste disposal facilities, or for both, within communities identified under paragraph (1). Not more than one community in any State shall be eligible for grants under this paragraph and not more than one project in any State shall be eligible for such grants.

"(3) Grants under this subsection shall be made only to projects which the Administrator determines will be consistent with an applicable State plan approved under this subtitle and which will assist in carrying out such plan.

"RURAL COMMUNITIES ASSISTANCE"

"**SEC. 4000. (a) IN GENERAL.**—The Administrator shall make grants to States to provide assistance to municipalities with a population of five thousand or less, or counties with a population of ten thousand or less or less than twenty persons per square mile and not within a metropolitan area, for solid waste management facilities (including equipment) necessary to meet the requirements of section 4005 of this Act or restrictions on open burning or other requirements arising under the Clean Air Act or the Federal Water Pollution Control Act. Such assistance shall only be available—

"(1) to any municipality or county which could not feasibly be included in a solid waste management system or facility serving an urbanized, multifurisdictional area because of its distance from such systems;

Note, p.

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"(2) where existing or planned solid waste management services or facilities are unavailable or insufficient to comply with the requirements of section 4005 of this Act; and

"(3) for systems which are certified by the State to be consistent with any plans or programs established under any State or areawide planning process.

"(b) ALLOTMENT.—The Administrator shall allot the sums appropriated to carry out this section in any fiscal year among the States in accordance with regulations promulgated by him on the basis of the average of the ratio which the population of rural areas of each State bears to the total population of rural areas of all the States, the ratio which the population of counties in each State having less than twenty persons per square mile bears to the total population of such counties in all the States, and the ratio which the population of such low-density counties in each State having 83 per centum or more of all families with incomes not in excess of 125 per centum of the poverty level bears to the total population of such counties in all the States.

Land acquisition,
prohibition.

"(c) LIMIT.—The amount of any grant under this section shall not exceed 75 per centum of the costs of the project. No assistance under this section shall be available for the acquisition of land or interest in land.

"(d) APPROPRIATIONS.—There are authorized to be appropriated \$25,000,000 for each of the fiscal years 1978 and 1979 to carry out this section.

"Subtitle E—Duties of the Secretary of Commerce in Resource and Recovery

"FUNCTIONS

42 USC 6951.

"SEC. 5001. The Secretary of Commerce shall encourage greater commercialization of proven resource recovery technology by providing—

- "(1) accurate specifications for recovered materials;
- "(2) stimulation of development of markets for recovered materials;
- "(3) promotion of proven technology; and
- "(4) a forum for the exchange of technical and economic data relating to resource recovery facilities.

"DEVELOPMENT OF SPECIFICATIONS FOR SECONDARY MATERIALS

Publication of
guidelines.
42 USC 6952.

"SEC. 5002. The Secretary of Commerce, acting through the National Bureau of Standards, and in conjunction with national standards-setting organizations in resource recovery, shall, after public hearings, and not later than two years after the date of the enactment of this Act, publish guidelines for the development of specifications for the classification of materials recovered from waste which were destined for disposal. The specifications shall pertain to the physical and chemical properties and characteristics of such materials with regard to their use in replacing virgin materials in various industrial, commercial, and governmental uses. In establishing such guidelines the Secretary shall also, to the extent feasible, provide such information as may be necessary to assist Federal agencies with procurement of items containing recovered materials. The Secretary shall continue to cooperate with national standards-setting organizations as may be necessary, to encourage the publication, promulgation and

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updating of standards for recovered materials and for the use of recovered materials in various industrial, commercial, and governmental uses.

"DEVELOPMENT OF MARKETS FOR RECOVERED MATERIALS

"Sec. 5003. The Secretary of Commerce shall within two years after the enactment of this Act take such actions as may be necessary to— 42 USC 66

"(1) identify the geographical location of existing or potential markets for recovered materials;

"(2) identify the economic and technical barriers to the use of recovered materials; and

"(3) encourage the development of new uses for recovered materials.

"TECHNOLOGY PROMOTION

"Sec. 5004. The Secretary of Commerce is authorized to evaluate the commercial feasibility of resource recovery facilities and to publish the results of such evaluation, and to develop a data base for purposes of assisting persons in choosing such a system. 42 USC 69

"Subtitle F—Federal Responsibilities

**"APPLICATION OF FEDERAL, STATE, AND LOCAL LAW TO
FEDERAL FACILITIES**

"Sec. 6001. Each department, agency, and instrumentality of the executive, legislative, and judicial branches of the Federal Government (1) having jurisdiction over any solid waste management facility or disposal site, or (2) engaged in any activity resulting, or which may result, in the disposal of solid waste or hazardous waste shall be subject to, and comply with, all Federal, State, interstate, and local requirements, both substantive and procedural (including any requirement for permits or reporting or any provisions for injunctive relief and such sanctions as may be imposed by a court to enforce such relief), respecting control and abatement of solid waste or hazardous waste disposal in the same manner, and to the same extent, as any person is subject to such requirements, including the payment of reasonable service charges. Neither the United States, nor any agent, employee, or officer thereof, shall be immune or exempt from any process or sanction of any State or Federal Court with respect to the enforcement of any such injunctive relief. The President may exempt any solid waste management facility of any department, agency, or instrumentality in the executive branch from compliance with such a requirement if he determines it to be in the paramount interest of the United States to do so. No such exemption shall be granted due to lack of appropriation unless the President shall have specifically requested such appropriation as a part of the budgetary process and the Congress shall have failed to make available such requested appropriation. Any exemption shall be for a period not in excess of one year, but additional exemptions may be granted for periods not to exceed one year upon the President's making a new determination. The President shall report each January to the Congress all exemptions from the requirements of this section granted during the preceding calendar year, together with his reason for granting each such exemption. 42 USC 69

Exemptions.

Presidential
report to
Congress.

"FEDERAL PROCUREMENT"

USC 6962.

"Sec. 6002. (a) APPLICATION OF SECTION.—Except as provided in subsection (b), a procuring agency shall comply with the requirements set forth in this section and any regulations issued under this section, with respect to any purchase or acquisition of a procurement item where the purchase price of the item exceeds \$10,000 or where the quantity of such items or of functionally equivalent items purchased or acquired in the course of the preceding fiscal year was \$10,000 or more.

"(b) PROCUREMENT SUBJECT TO OTHER LAW.—Any procurement, by any procuring agency, which is subject to regulations of the Administrator under section 6004 (as promulgated before the date of enactment of this section under comparable provisions of prior law) shall not be subject to the requirements of this section to the extent that such requirements are inconsistent with such regulations.

"(c) REQUIREMENTS.—(1) (A) After two years after the date of enactment of this section, each procuring agency shall procure items composed of the highest percentage of recovered materials practicable consistent with maintaining a satisfactory level of competition. The decision not to procure such items shall be based on a determination that such procurement items—

"(i) are not reasonably available within a reasonable period of time;

"(ii) fail to meet the performance standards set forth in the applicable specifications or fail to meet the reasonable performance standards of the procuring agencies; or

"(iii) are only available at an unreasonable price. Any determination under clause (ii) shall be made on the basis of the guidelines of the Bureau of Standards in any case in which such material is covered by such guidelines.

"(B) Agencies that generate heat, mechanical, or electrical energy from fossil fuel in systems that have the technical capability of using recovered material and recovered-material-derived fuel as a primary or supplementary fuel shall use such capability to the maximum extent practicable.

"(C) Contracting officers shall require that vendors certify the percentage of the total material utilized for the performance of the contract which is recovered materials.

"(d) SPECIFICATIONS.—(1) All Federal agencies that have the responsibility for drafting or reviewing specifications for procurement item procured by Federal agencies shall, in reviewing those specifications, ascertain whether such specifications violate the prohibitions contained in subparagraphs (A) through (C) of paragraph (2). Such review shall be undertaken not later than eighteen months after the date of enactment of this section.

"(2) In drafting or revising such specifications, after the date of enactment of this section—

"(A) any exclusion of recovered materials shall be eliminated;

"(B) such specification shall not require the item to be manufactured from virgin materials; and

"(C) such specifications shall require reclaimed materials to the maximum extent possible without jeopardizing the intended end use of the item.

"(e) GUIDELINES.—The Administrator, after consultation with the Administrator of General Services, the Secretary of Commerce (and

prepare, and from time to time revise, guidelines for the use of procuring agencies in complying with the requirements of this section. Such guidelines shall set forth recommended practices with respect to the procurement of recovered materials and items containing such materials and shall provide information as to the availability, sources of supply, and potential uses of such materials and items.

"(f) **PROCUREMENT OF SERVICES.**—A procuring agency shall, to the maximum extent practicable, manage or arrange for the procurement of solid waste management services in a manner which maximizes energy and resource recovery.

"(g) **EXECUTIVE OFFICE.**—The Office of Procurement Policy in the Executive Office of the President, in cooperation with the Administrator, shall implement the policy expressed in this section. It shall be the responsibility of the Office of Procurement Policy to coordinate this policy with other policies for Federal procurement, in such a way as to maximize the use of recovered resources, and to annually report to the Congress on actions taken by Federal agencies and the progress made in the implementation of such policy.

"COOPERATION WITH ENVIRONMENTAL PROTECTION AGENCY

"Sec. 6003. All Federal agencies having functions relating to solid waste or hazardous waste shall cooperate to the maximum extent permitted by law with the Administrator in carrying out his functions under this Act and shall make all appropriate information, facilities, personnel, and other resources available, on a reimbursable basis, to the Administrator upon his request. 42 USC 6

"APPLICABILITY OF SOLID WASTE DISPOSAL GUIDELINES TO EXECUTIVE AGENCIES

"Sec. 6004. (a) **COMPLIANCE.**—(1) If— 42 USC 69

"(A) an Executive agency (as defined in section 105 of title 5, United States Code) has jurisdiction over any real property or facility the operation or administration of which involves such agency in solid waste disposal activities, or

"(B) such an agency enters into a contract with any person for the operation by such person of any Federal property or facility, and the performance of such contract involves such person in solid waste disposal activities,

then such agency shall insure compliance with the guidelines recommended under section 1008 and the purposes of this Act in the operation or administration of such property or facility, or the performance of such contract, as the case may be. Antc, p. 20

"(2) Each Executive agency which conducts any activity—

"(A) which generates solid waste, and

"(B) which, if conducted by a person other than such agency, would require a permit or license from such agency in order to dispose of such solid waste,

shall insure compliance with such guidelines and the purposes of this Act in conducting such activity.

"(3) Each Executive agency which permits the use of Federal property for purposes of disposal of solid waste shall insure compliance with such guidelines and the purposes of this Act in the disposal of such waste.

"(4) The President shall prescribe regulations to carry out this subsection.

1803. "(b) LICENSES AND PERMITS.—Each Executive agency which issues any license or permit for disposal of solid waste shall, prior to the issuance of such license or permit, consult with the Secretary to insure compliance with guidelines recommended under section 1008 and the purposes of this Act.

"Subtitle C—Miscellaneous Provisions

"EMPLOYEE PROTECTION

1971. "SEC. 7001. (a) GENERAL.—No person shall fire, or in any other way discriminate against, or cause to be fired or discriminated against, any employee or any authorized representative of employees by reason of the fact that such employee or representative has filed, instituted, or caused to be filed or instituted any proceeding under this Act or under any applicable implementation plan, or has testified or is about to testify in any proceeding resulting from the administration or enforcement of the provisions of this Act or of any applicable implementation plan.

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"(b) REMEDY.—Any employee or a representative of employees who believes that he has been fired or otherwise discriminated against by any person in violation of subsection (a) of this section may, within thirty days after such alleged violation occurs, apply to the Secretary of Labor for a review of such firing or alleged discrimination. A copy of the application shall be sent to such person who shall be the respondent. Upon receipt of such application, the Secretary of Labor shall cause such investigation to be made as he deems appropriate. Such investigation shall provide an opportunity for a public hearing at the request of any party to such review to enable the parties to present information relating to such alleged violation. The parties shall be given written notice of the time and place of the hearing at least five days prior to the hearing. Any such hearing shall be of record and shall be subject to section 554 of title 5 of the United States Code. Upon receiving the report of such investigation, the Secretary of Labor shall make findings of fact. If he finds that such violation did occur, he shall issue a decision, incorporating an order therein and his findings, requiring the party committing such violation to take such affirmative action to abate the violation as the Secretary of Labor deems appropriate, including, but not limited to, the rehiring or reinstatement of the employee or representative of employees to his former position with compensation. If he finds that there was no such violation, he shall issue an order denying the application. Such order issued by the Secretary of Labor under this subparagraph shall be subject to judicial review in the same manner as orders and decisions of the Administrator or subject to judicial review under this Act.

"(c) COSTS.—Whenever an order is issued under this section to abate such violation, at the request of the applicant, a sum equal to the aggregate amount of all costs and expenses (including the attorney's fees) as determined by the Secretary of Labor, to have been reasonably incurred by the applicant for, or in connection with, the institution and prosecution of such proceedings, shall be assessed against the person committing such violation.

"(d) EXCEPTION.—This section shall have no application to any employee who, acting without direction from his employer (or his agent) deliberately violates any requirement of this Act.

"(e) EMPLOYMENT SHIFTS AND LOSS.—The Administrator shall

ment which may result from the administration or enforcement of the provisions of this Act and applicable implementation plans, including, where appropriate, investigating threatened plant closures or reductions in employment allegedly resulting from such administration or enforcement. Any employee who is discharged, or laid off, threatened with discharge or layoff, or otherwise discriminated against by any person because of the alleged results of such administration or enforcement, or any representative of such employee, may request the Administrator to conduct a full investigation of the matter. The Administrator shall thereupon investigate the matter and, at the request of any party, shall hold public hearings on not less than five days' notice, and shall at such hearings require the parties, including the employer involved, to present information relating to the actual or potential effect of such administration or enforcement on employment and on any alleged discharge, layoff, or other discrimination and the detailed reasons or justification therefor. Any such hearing shall be of record and shall be subject to section 554 of title 5 of the United States Code. Upon receiving the report of such investigation, the Administrator shall make findings of fact as to the effect of such administration or enforcement on employment and on the alleged discharge, layoff, or discrimination and shall make such recommendations as he deems appropriate. Such report, findings, and recommendations shall be available to the public. Nothing in this subsection shall be construed to require or authorize the Administrator or any State to modify or withdraw any standard, limitation, or any other requirement of this Act or any applicable implementation plan.

Request for
investigation

Hearing.

Report, findings
and recommendations,
available to public.

"CITIZEN SUITS

"Sec. 7002. (a) IN GENERAL.—Except as provided in subsection (b) or (c) of this section, any person may commence a civil action on his own behalf—

42 USC. 69

"(1) against any person (including (a) the United States, and (b) any other governmental instrumentality or agency, to the extent permitted by the eleventh amendment to the Constitution) who is alleged to be in violation of any permit, standard, regulation, condition, requirement, or order which has become effective pursuant to this Act; or

"(2) against the Administrator where there is alleged a failure of the Administrator to perform any act or duty under this Act which is not discretionary with the Administrator.

Any action under paragraph (a)(1) of this subsection shall be brought in the district court for the district in which the alleged violation occurred. Any action brought under paragraph (a)(2) of this subsection may be brought in the district court for the district in which the alleged violation occurred or in the District Court of the District of Columbia. The district court shall have jurisdiction, without regard to the amount in controversy or the citizenship of the parties, to enforce such regulation or order, or to order the Administrator to perform such act or duty as the case may be.

"(b) Across Frontiers.—No action may be commenced under paragraph (a)(1) of this section—

"(1) prior to sixty days after the plaintiff has given notice of the violation (A) to the Administrator; (B) to the State in which the alleged violation occurs; and (C) to any alleged violator of such permit, standard, regulation, condition, requirement, or order; or

"(2) if the Administrator or State has commenced and is diligently prosecuting a civil or criminal action in a court of the United States or a State to require compliance with such permit, standard, regulation, condition, requirement, or order: *Provided, however,* That in any such action in a court of the United States, any person may intervene as a matter of right.

SC 3254f.

"(c) **NOTICE.**—No action may be commenced under paragraph (a) (2) of this section prior to sixty days after the plaintiff has given notice to the Administrator that he will commence such action, except that such action may be brought immediately after such notification in the case of an action under this section respecting a violation of section 212 of this Act. Notice under this subsection shall be given in such manner as the Administrator shall prescribe by regulation. Any action respecting a violation under this Act may be brought under this section only in the judicial district in which such alleged violation occurs.

"(d) **INTERVENTION.**—In any action under this section the Administrator, if not a party, may intervene as a matter of right.

SC app.

"(e) **COSTS.**—The court, in issuing any final order in any action brought pursuant to this section, may award costs of litigation (including reasonable attorney and expert witness fees) to any party, whenever the court determines such an award is appropriate. The court may, if a temporary restraining order or preliminary injunction is sought, requiring the filing of a bond or equivalent security in accordance with the Federal Rules of Civil Procedure.

"(f) **OTHER RIGHTS PRESERVED.**—Nothing in this section shall restrict any right which any person (or class of persons) may have under any statute or common law to seek enforcement of any standard or requirement relating to the management of solid waste or hazardous waste, or to seek any other relief (including relief against the Administrator or a State agency).

"IMMINENT HAZARD

SC 6973.

"Sec. 7003. Notwithstanding any other provision of this Act, upon receipt of evidence that the handling, storage, treatment, transportation or disposal of any solid waste or hazardous waste is presenting an imminent and substantial endangerment to health or the environment, the Administrator may bring suit on behalf of the United States in the appropriate district court to immediately restrain any person for contributing to the alleged disposal to stop such handling, storage, treatment, transportation, or disposal or to take such other action as may be necessary. The Administrator shall provide notice to the affected State of any such suit.

"PETITION FOR REGULATIONS; PUBLIC PARTICIPATION

ation in
al Register.
SC 6974.

"Sec. 7004. (a) **PETITION.**—Any person may petition the Administrator for the promulgation, amendment, or repeal of any regulation under this Act. Within a reasonable time following receipt of such petition, the Administrator shall take action with respect to such petition and shall publish notice of such action in the Federal Register, together with the reasons therefor.

"(b) **PUBLIC PARTICIPATION.**—Public participation in the development, revision, implementation, and enforcement of any regulation, guideline, information, or program under this Act shall be provided

The Administrator, in cooperation with the States, shall develop and publish minimum guidelines for public participation in such processes.

"SEPARABILITY

"SEC. 7005. If any provision of this Act, or the application of any provision of this Act to any person or circumstance, is held invalid, the application of such provision to other persons or circumstances, and the remainder of this Act, shall not be affected thereby. 42 USC 69"

"JUDICIAL REVIEW

"SEC. 7006. Any judicial review of final regulations promulgated pursuant to this Act shall be in accordance with sections 701 through 706 of title 5 of the United States Code, except that— 42 USC 69"

"(1) a petition for review of action of the Administrator in promulgating any regulation, or requirement under this Act may be filed only in the United States Court of Appeals for the District of Columbia. Any such petition shall be filed within ninety days from the date of such promulgation, or after such date if such petition is based solely on grounds arising after such ninetieth day. Action of the Administrator with respect to which review could have been obtained under this subsection shall not be subject to judicial review in civil or criminal proceedings for enforcement; and

"(2) in any judicial proceeding brought under this section in which review is sought of a determination under this Act required to be made on the record after notice and opportunity for hearing, if a party seeking review under this Act applies to the court for leave to adduce additional evidence, and shows to the satisfaction of the court that the information is material and that there were reasonable grounds for the failure to adduce such evidence in the proceeding before the Administrator, the court may order such additional evidence (and evidence in rebuttal thereof) to be taken before the Administrator, and to be adduced upon the hearing in such manner and upon such terms and conditions as the court may deem proper. The Administrator may modify his findings as to the facts, or make new findings, by reason of the additional evidence so taken, and he shall file with the court such modified or new findings and his recommendation, if any, for the modification or setting aside of his original order, with the return of such additional evidence.

"GRANTS OR CONTRACTS FOR TRAINING PROJECTS

"SEC. 7007. (a) GENERAL AUTHORITY.—The Administrator is authorized to make grants to, and contracts with any eligible organization. For purposes of this section the term "eligible organization" means a State or interstate agency, a municipality, educational institution, and any other organization which is capable of effectively carrying out a project which may be funded by grant under subsection (b) of this section. 42 USC 697"

"(b) PURPOSES.—(1) Subject to the provisions of paragraph (2), grants or contracts may be made to pay all or a part of the costs, as may be determined by the Administrator, of any project operated or to be operated by an eligible organization, which is designed

"(A) to develop, expand, or carry out a program (which may

"Eligible organization."

combine training, education, and employment) for training persons for occupations involving the management, supervision, design, operation, or maintenance of solid waste disposal and resources recovery equipment and facilities; or

"(1) to train instructors and supervisory personnel to train or supervise persons in occupations involving the design, operation, and maintenance of solid waste disposal and resource recovery equipment and facilities.

"(2) A grant or contract authorized by paragraph (1) of this subsection may be made only upon application to the Administrator at such time or times and containing such information as he may prescribe, except that no such application shall be approved unless it provides for the same procedures and reports (and access to such reports and to other records) as required by section 207(b) (4) and (5) (as in effect before the date of the enactment of Resource Conservation and Recovery Act of 1976) with respect to applications made under such section (as in effect before the date of the enactment of Resource Conservation and Recovery Act of 1976).

"(c) STUDY.—The Administrator shall make a complete investigation and study to determine—

"(1) the need for additional trained State and local personnel to carry out plans assisted under this Act and other solid waste and resource recovery programs;

"(2) means of using existing training programs to train such personnel; and

"(3) the extent and nature of obstacles to employment and occupational advancement in the solid waste disposal and resource recovery field which may limit either available manpower or the advancement of personnel in such field.

He shall report the results of such investigation and study, including his recommendations to the President and the Congress.

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"PAYMENTS

SC 6978.

"SEC. 7008. (a) GENERAL RULE.—Payments of grants under this Act may be made (after necessary adjustment on account of previously made underpayments or overpayments) in advance or by way of reimbursement, and in such installments and on such conditions as the Administrator may determine.

"(b) PROHIBITION.—No grant may be made under this Act to any private profitmaking organization.

"LABOR STANDARDS

SC 6979.

"SEC. 7009. No grant for a project of construction under this Act shall be made unless the Secretary finds that the application contains or is supported by reasonable assurance that all laborers and mechanics employed by contractors or subcontractors on projects of the type covered by the Davis-Bacon Act, as amended (40 U.S.C. 276a—276a-5), will be paid wages at rates not less than those prevailing on similar work in the locality as determined by the Secretary of Labor in accordance with that Act; and the Secretary of Labor shall have with respect to the labor standards specified in this section the authority and functions set forth in Reorganization Plan Numbered 14 of 1950 (15 F.R. 3176; 5 U.S.C. 1332-5) and section 2 of the Act of June 13, 1934, as amended (40 U.S.C. 276c).

C app. II.

"Subtitle II—Research, Development, Demonstration, and
Information

"RESEARCH, DEMONSTRATIONS, TRAINING, AND OTHER ACTIVITIES

"SEC. 8001. (a) (GENERAL AUTHORITY.—The Administrator, alone or after consultation with the Administrator of the Federal Energy Administration, the Administrator of the Energy Research and Development Administration, or the Chairman of the Federal Power Commission, shall conduct, and encourage, cooperate with, and render financial and other assistance to appropriate public (whether Federal, State, interstate, or local) authorities, agencies, and institutions, private agencies and institutions, and individuals in the conduct of, and promote the coordination of, research, investigations, experiments, training, demonstrations, surveys, public education programs, and studies relating to—

42 USC 6981.

"(1) any adverse health and welfare effects of the release into the environment of material present in solid waste, and methods to eliminate such effects;

"(2) the operation and financing of solid waste disposal programs;

"(3) the planning, implementation, and operation of resource recovery and resource conservation systems and hazardous waste management systems, including the marketing of recovered resources;

"(4) the production of usable forms of recovered resources, including fuel, from solid waste;

"(5) the reduction of the amount of such waste and unsalvageable waste materials;

"(6) the development and application of new and improved methods of collecting and disposing of solid waste and processing and recovering materials and energy from solid wastes;

"(7) the identification of solid waste components and potential materials and energy recoverable from such waste components;

"(8) small scale and low technology solid waste management systems, including but not limited to, resource recovery source separation systems;

"(9) methods to improve the performance characteristics of resources recovered from solid waste and the relationship of such performance characteristics to available and potentially available markets for such resources;

"(10) improvements in land disposal practices for solid waste (including sludge) which may reduce the adverse environmental effects of such disposal and other aspects of solid waste disposal on land, including means for reducing the harmful environmental effects of earlier and existing landfills, means for restoring areas damaged by such earlier or existing landfills, means for rendering landfills safe for purposes of construction and other uses, and techniques of recovering materials and energy from landfills;

"(11) methods for the sound disposal of, or recovery of resources, including energy, from, sludge (including sludge from pollution control and treatment facilities, coal slurry pipelines, and other sources);

"(12) methods of hazardous waste management, including methods of rendering such waste environmentally safe; and

"(13) any adverse effects on air quality (particularly with

regard to the emission of heavy metals) which result from solid waste which is burned (either alone or in conjunction with other substances) for purposes of disposal or energy recovery.

"(b) MANAGEMENT PROGRAM.—(1) (A) In carrying out his functions pursuant to this Act, and any other Federal legislation respecting solid waste or discarded material research, development, and demonstrations, the Administrator shall establish a management program or system to insure the coordination of all such activities and to facilitate and accelerate the process of development of sound new technology (or other discoveries) from the research phase, through development, and into the demonstration phase.

"(B) The Administrator shall (i) assist, on the basis of any research projects which are developed with assistance under this Act or without Federal assistance, the construction of pilot plant facilities for the purpose of investigating or testing the technological feasibility of any promising new fuel, energy, or resource recovery or resource conservation method or technology; and (ii) demonstrate each such method and technology that appears justified by an evaluation at such pilot plant stage or at a pilot plant stage developed without Federal assistance. Each such demonstration shall incorporate new or innovative technical advances or shall apply such advances to different circumstances and conditions, for the purpose of evaluating design concepts or to test the performance, efficiency, and economic feasibility of a particular method or technology under actual operating conditions. Each such demonstration shall be so planned and designed that, if successful, it can be expanded or utilized directly as a full-scale operational fuel, energy, or resource recovery or resource conservation facility.

"(2) Any energy-related research, development, or demonstration project for the conversion including bioconversion, of solid waste carried out by the Environmental Protection Agency or by the Energy Research and Development Administration pursuant to this or any other Act shall be administered in accordance with the May 7, 1976, Interagency Agreement between the Environmental Protection Agency and the Energy Research and Development Administration on the Development of Energy from Solid Wastes and specifically, that in accordance with this agreement, (A) for those energy-related projects of mutual interest, planning will be conducted jointly by the Environmental Protection Agency and the Energy Research and Development Administration, following which project responsibility will be assigned to one agency; (B) energy-related portions of projects for recovery of synthetic fuels or other forms of energy from solid waste shall be the responsibility of the Energy Research and Development Administration; (C) the Environmental Protection Agency shall retain responsibility for the environmental, economic, and institutional aspects of solid waste projects and for assurance that such projects are consistent with any applicable suggested guidelines published pursuant to section 1008, and any applicable State or regional solid waste management plan; and (D) any activities undertaken under provisions of sections 8002 and 8003 as related to energy; as related to energy or synthetic fuels recovery from waste; or as related to energy conservation shall be accomplished through coordination and consultation with the Energy Research and Development Administration.

"(c) ACTIVITIES.—(1) In carrying out subsection (a) of this section respecting solid waste research, studies, development, and demon-

stration, except as otherwise specifically provided in section 8004(d), the Administrator may make grants to or enter into contracts (including contracts for construction) with, public agencies and authorities or private persons.

"(2) Contracts for research, development, or demonstrations or for both (including contracts for construction) shall be made in accordance with and subject to the limitations provided with respect to research contracts of the military departments in title 10, United States Code, section 2353, except that the determination, approval, and certification required thereby shall be made by the Administrator.

"(3) Any invention made or conceived in the course of, or under, any contract under this Act shall be subject to section 9 of the Federal Nonnuclear Energy Research and Development Act of 1974 to the same extent and in the same manner as inventions made or conceived in the course of contracts under such Act, except that in applying such section, the Environmental Protection Agency shall be substituted for the Energy Research and Development Administration and the words 'solid waste' shall be substituted for the word 'energy' where appropriate.

42 USC 590:

"(4) For carrying out the purpose of this Act the Administrator may detail personnel of the Environmental Protection Agency to agencies eligible for assistance under this section.

Detail of
EPA personnel
other agency

**"SPECIAL STUDIES; PLANS FOR RESEARCH, DEVELOPMENT, AND
DEMONSTRATIONS**

"SEC. 8002. (a) GLASS AND PLASTIC.—The Administrator shall undertake a study and publish a report on resource recovery from glass and plastic waste, including a scientific, technological, and economic investigation of potential solutions to implement such recovery.

42 USC 698:

"(b) COMPOSITION OF WASTE STREAM.—The Administrator shall undertake a systematic study of the composition of the solid waste stream and of anticipated future changes in the composition of such stream and shall publish a report containing the results of such study and quantitatively evaluating the potential utility of such components.

"(c) PRIORITIES STUDY.—For purposes of determining priorities for research on recovery of materials and energy from solid waste and developing materials and energy recovery research, development, and demonstration strategies, the Administrator shall review, and make a study of, the various existing and promising techniques of energy recovery from solid waste (including, but not limited to, waterwall furnace incinerators, dry shredded fuel systems, pyrolysis, densified refuse-derived fuel systems, anaerobic digestion, and fuel and feedstock preparation systems). In carrying out such study the Administrator shall investigate with respect to each such technique—

"(1) the degree of public need for the potential results of such research, development, or demonstration,

"(2) the potential for research, development, and demonstration without Federal action, including the degree of restraint on such potential posed by the risks involved, and

"(3) the magnitude of effort and period of time necessary to develop the technology to the point where Federal assistance can be ended.

"(d) SMALL-SCALE AND LOW TECHNOLOGY STUDY.—The Administrator shall undertake a comprehensive study and analysis of, and publish a report on, systems of small-scale and low technology solid

waste management, including household resource recovery and resource recovery systems which have special application to multiple dwelling units and high density housing and office complexes. Such study and analysis shall include an investigation of the degree to which such systems could contribute to energy conservation.

"(e) **Front-End Source Separation.**—The Administrator shall undertake research and studies concerning the compatibility of front-end source separation systems with high technology resource recovery systems and shall publish a report containing the results of such research and studies.

"(f) **Mining Waste.**—The Administrator, in consultation with the Secretary of the Interior, shall conduct a detailed and comprehensive study on the adverse effects of solid wastes from active and abandoned surface and underground mines on the environment, including, but not limited to, the effects of such wastes on humans, water, air, health, welfare, and natural resources, and on the adequacy of means and measures currently employed by the mining industry, Government agencies, and others to dispose of and utilize such solid wastes and to prevent or substantially mitigate such adverse effects. Such study shall include an analysis of—

"(1) the sources and volume of discarded material generated per year from mining;

"(2) present disposal practices;

"(3) potential dangers to human health and the environment from surface runoff of leachate and air pollution by dust;

"(4) alternatives to current disposal methods;

"(5) the cost of those alternatives in terms of the impact on mine product costs; and

"(6) potential for use of discarded material as a secondary source of the mine product.

In furtherance of this study, the Administrator shall, as he deems appropriate, review studies and other actions of other Federal agencies concerning such wastes with a view toward avoiding duplication of effort and the need to expedite such study. The Administrator shall publish a report of such study and shall include appropriate findings and recommendations for Federal and non-Federal actions concerning such effects.

"(g) **Sludge.**—The Administrator shall undertake a comprehensive study and publish a report on sludge. Such study shall include an analysis of—

"(1) what types of solid waste (including but not limited to sewage and pollution treatment residues and other residues from industrial operations such as extraction of oil from shale liquefaction and gasification of coal and coal slurry pipeline operations) shall be classified as sludge;

"(2) the effects of air and water pollution legislation on the creation of large volumes of sludge;

"(3) the amounts of sludge originating in each State and in each industry producing sludge;

"(4) methods of disposal of such sludge, including the cost, efficiency, and effectiveness of such methods;

"(5) alternative methods for the use of sludge, including agricultural applications of sludge and energy recovery from sludge; and

"(6) methods to reclaim areas which have been used for the disposal of sludge or which have been damaged by sludge.

"(h) **Tires.**—The Administrator shall undertake a study and publish a report respecting discarded motor vehicle tires which shall include an analysis of the problems involved in the collection, recovery of resources including energy, and use of such tires.

"(i) **Resource Recovery Facilities.**—The Administrator shall conduct research and report on the economics of, and impediments, to the effective functioning of resource recovery facilities.

"(j) **Resource Conservation Committee.**—(1) The Administrator shall serve as Chairman of a Committee composed of himself, the Secretary of Commerce, the Secretary of Labor, the Chairman of the Council on Environmental Quality, the Secretary of Treasury, the Secretary of the Interior, and a representative of the Office of Management and Budget, which shall conduct a full and complete investigation and study of all aspects of the economic, social, and environmental consequences of resource conservation with respect to—

"(A) the appropriateness of recommended incentives and disincentives to foster resource conservation;

"(B) the effect of existing public policies (including subsidies and economic incentives and disincentives, percentage depletion allowances, capital gains treatment and other tax incentives and disincentives) upon resource conservation, and the likely effect of the modification or elimination of such incentives and disincentives upon resource conservation;

"(C) the appropriateness and feasibility of restricting the manufacture or use of categories of consumer products as a resource conservation strategy;

"(D) the appropriateness and feasibility of employing as a resource conservation strategy the imposition of solid waste management charges on consumer products, which charges would reflect the costs of solid waste management services, litter pickup, the value of recoverable components of such product, final disposal, and any social value associated with the nonrecycling or uncontrolled disposal of such product; and

"(E) the need for further research, development, and demonstration in the area of resource conservation.

"(2) The study required in paragraph (2)(D) may include pilot scale projects, and shall consider and evaluate alternative strategies with respect to—

Pilot area projects.

"(A) the product categories on which such charges would be imposed;

"(B) the appropriate state in the production of such consumer product at which to levy such charge;

"(C) appropriate criteria for establishing such charges for each consumer product category;

"(D) methods for the adjustment of such charges to reflect actions such as recycling which would reduce the overall quantities of solid waste requiring disposal; and

"(E) procedures for amending, modifying, or revising such charges to reflect changing conditions.

"(3) The design for the study required in paragraph (2)(D) of this subsection shall include timetables for the completion of the study. A preliminary report putting forth the study design shall be sent to the President and the Congress within six months following enactment of this section and followup reports shall be sent six months thereafter. Each recommendation resulting from the study shall include at least two alternatives to the proposed recommendation.

Study design

Report to President Congress.

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"(4) The results of such investigation and study, including recommendations, shall be reported to the President and the Congress not later than two years after enactment of this subsection.

"(5) There are authorized to be appropriated not to exceed \$2,000,000 to carry out this subsection.

"(k) AIRPORT LANDFILLS.—The Administrator shall undertake a comprehensive study and analysis of and publish a report on systems to alleviate the hazards to aviation from birds congregating and feeding on landfills in the vicinity of airports.

"(l) COMPLETION OF RESEARCH AND STUDIES.—The Administrator shall complete the research and studies, and submit the reports, required under subsections (b), (c), (d), (e), (f), (g), and (k) not later than October 1, 1978. The Administrator shall complete the research and studies, and submit the reports, required under subsections (a), (h), (i), and (j) not later than October 1, 1979. Upon completion, each study specified in subsections (a) through (k) of this section, the Administrator shall prepare a plan for research, development, and demonstration respecting the findings of the study and shall submit any legislative recommendations resulting from such study to appropriate committees of Congress.

"(m) AUTHORIZATION OF APPROPRIATIONS.—There are authorized to be appropriated not to exceed \$8,000,000 for the fiscal years 1978 and 1979 to carry out this section other than subsection (j).

"COORDINATION, COLLECTION, AND DISSEMINATION OF INFORMATION

HC 6983.

"SEC. 8003. (a) INFORMATION.—The Administrator shall develop, collect, evaluate, and coordinate information on—

"(1) methods and costs of the collection of solid waste;

"(2) solid waste management practices, including data on the different management methods and the cost, operation, and maintenance of such methods;

"(3) the amounts and percentages of resources (including energy) that can be recovered from solid waste by use of various discarded materials management practices and various technologies;

"(4) methods available to reduce the amount of solid waste that is generated;

"(5) existing and developing technologies for the recovery of energy or materials from solid waste and the costs, reliability, and risks associated with such technologies;

"(6) hazardous solid waste, including incidents of damage resulting from the disposal of hazardous solid wastes; inherently and potentially hazardous solid wastes; methods of neutralizing or properly disposing of hazardous solid wastes; facilities that properly dispose of hazardous wastes;

"(7) methods of financing resource recovery facilities or, sanitary landfills, or hazardous solid waste treatment facilities, whichever is appropriate for the entity developing such facility or landfill (taking into account the amount of solid waste reasonably expected to be available to such entity);

"(8) the availability of markets for the purchase of resources, either materials or energy, recovered from solid waste; and

"(9) research and development projects respecting solid waste management.

"(b) **LIBRARY.**—(1) The Administrator shall establish and maintain a central reference library for (A) the materials collected pursuant to subsection (a) of this section and (B) the actual performance and cost effectiveness records and other data and information with respect to—

"(i) the various methods of energy and resource recovery from solid waste,

"(ii) the various systems and means of resource conservation,

"(iii) the various systems and technologies for collection, transport, storage, treatment, and final disposition of solid waste, and

"(iv) other aspects of solid waste and hazardous solid waste management.

Such central reference library shall also contain, but not be limited to, the model codes and model accounting systems developed under this section, the information collected under subsection (d), and, subject to any applicable requirements of confidentiality, information respecting any aspect of solid waste provided by officers and employees of the Environmental Protection Agency which has been acquired by them in the conduct of their functions under this Act and which may be of value to Federal, State, and local authorities and other persons.

"(2) Information in the central reference library shall, to the extent practicable, be collated, analyzed, verified, and published and shall be made available to State and local governments and other persons at reasonable times and subject to such reasonable charges as may be necessary to defray expenses of making such information available.

"(c) **MODEL ACCOUNTING SYSTEM.**—In order to assist State and local governments in determining the cost and revenues associated with the collection and disposal of solid waste and with resource recovery operations, the Administrator shall develop and publish a recommended model cost and revenue accounting system applicable to the solid waste management functions of State and local governments. Such system shall be in accordance with generally accepted accounting principles. The Administrator shall periodically, but not less frequently than once every five years, review such accounting system and revise it as necessary.

"(d) **MODEL CODES.**—The Administrator is authorized, in cooperation with appropriate State and local agencies, to recommend model codes, ordinances, and statutes, providing for sound solid waste management.

"(e) **INFORMATION PROGRAMS.**—(1) The Administrator shall implement a program for the rapid dissemination of information on solid waste management, hazardous waste management, resource conservation, and methods of resource recovery from solid waste, including the results of any relevant research, investigations, experiments, surveys, studies, or other information which may be useful in the implementation of new or improved solid waste management practices and methods and information on any other technical, managerial, financial, or market aspect of resource conservation and recovery facilities.

"(2) The Administrator shall develop and implement educational programs to promote citizen understanding of the need for environmentally sound solid waste management practices.

"(f) **COORDINATION.**—In collecting and disseminating information under this section, the Administrator shall coordinate his actions and cooperate to the maximum extent possible with State and local authorities.

"(g) **SPECIAL RESTRICTION.**—Upon request, the full range of alternative technologies, programs or processes deemed feasible to meet the

resource recovery or resource conservation needs of a jurisdiction shall be described in such a manner as to provide a sufficient evaluative basis from which the jurisdiction can make its decisions, but no officer or employee of the Environmental Protection Agency shall, in an official capacity, lobby for or otherwise represent an agency position in favor of resource recovery or resource conservation, as a policy alternative for adoption into ordinances, codes, regulations, or law by any State or political subdivision thereof.

"FULL-SCALE DEMONSTRATION FACILITIES

84. "SEC. 8001.(a) AUTHORITY.—The Administrator may enter into contracts with public agencies or authorities or private persons for the construction and operation of a full-scale demonstration facility under this Act, or provide financial assistance in the form of grants to a full-scale demonstration facility under this Act only if the Administrator finds that—

"(1) such facility or proposed facility will demonstrate at full scale a new or significantly improved technology or process, a practical and significant improvement in discarded material management practice, or the technological feasibility and cost effectiveness of an existing, but unproven technology, process, or practice, and will not duplicate any other Federal, State, local, or commercial facility which has been constructed or with respect to which construction has begun (determined as of the date action is taken by the Administrator under this Act),

"(2) such contract or assistance meets the requirements of section 8001 and meets other applicable requirements of the Act,

"(3) such facility will be able to comply with the guidelines published under section 1008 and with other laws and regulations for the protection of health and the environment,

"(4) in the case of a contract for construction or operation, such facility is not likely to be constructed or operated by State, local, or private persons or in the case of an application for financial assistance, such facility is not likely to receive adequate financial assistance from other sources, and

"(5) any Federal interest in, or assistance to, such facility will be disposed of or terminated, with appropriate compensation, within such period of time as may be necessary to carry out the basic objectives of this Act.

"(b) TIME LIMITATION.—No obligation may be made by the Administrator for financial assistance under this subtitle for any full-scale demonstration facility after the date ten years after the enactment of this section. No expenditure of funds for any such full-scale demonstration facility under this subtitle may be made by the Administrator after the date fourteen years after such date of enactment.

"(c) COST SHARING.—Wherever practicable, in constructing, operating, or providing financial assistance under this subtitle to a full-scale demonstration facility, the Administrator shall endeavor to enter into agreements and make other arrangements for maximum practicable cost sharing with other Federal, State, and local agencies, private persons, or any combination thereof.

"(2) The Administrator shall enter into arrangements, wherever practicable and desirable, to provide monitoring of full-scale solid waste facilities (whether or not constructed or operated under this

Act) for purposes of obtaining information concerning the performance, and other aspects, of such facilities. Where the Administrator provides only monitoring and evaluation instruments or personnel (or both) or funds for such instruments or personnel and provides no other financial assistance to a facility, notwithstanding section 8001(c)(3), title to any invention made or conceived of in the course of developing, constructing, or operating such facility shall not be required to vest in the United States and patents respecting such invention shall not be required to be issued to the United States.

"(d) **Prohibition.**—After the date of enactment of this section, the Administrator shall not construct or operate any full-scale facility (except by contract with public agencies or authorities or private persons).

"SPECIAL STUDY AND DEMONSTRATION PROJECTS ON RECOVERY OF USEFUL ENERGY AND MATERIALS

"Sec. 8005. (a) STUDIES.—The Administrator shall conduct studies and develop recommendations for administrative or legislative action on— 42 USC

"(1) means of recovering materials and energy from solid waste, recommended uses of such materials and energy for national or international welfare, including identification of potential markets for such recovered resources, the impact of distribution of such resources on existing markets, and potentials for energy conservation through resource conservation and resource recovery;

"(2) actions to reduce waste generation which have been taken voluntarily or in response to governmental action, and those which practically could be taken in the future, and the economic, social, and environmental consequences of such actions;

"(3) methods of collection, separation, and containerization which will encourage efficient utilization of facilities and contribute to more effective programs of reduction, reuse, or disposal of wastes;

"(4) the use of Federal procurement to develop market demand for recovered resources;

"(5) recommended incentives (including Federal grants, loans, and other assistance) and disincentives to accelerate the reclamation or recycling of materials from solid wastes, with special emphasis on motor vehicle hulks;

"(6) the effect of existing public policies, including subsidies and economic incentives and disincentives, percentage depletion allowances, capital gains treatment and other tax incentives and disincentives, upon the recycling and reuse of materials, and the likely effect of the modification or elimination of such incentives and disincentives upon the reuse, recycling and conservation of such materials;

"(7) the necessity and method of imposing disposal or other charges on packaging, containers, vehicles, and other manufactured goods, which charges would reflect the cost of final disposal, the value of recoverable components of the item, and any social costs associated with nonrecycling or uncontrolled disposal of such items; and

"(8) the legal constraints and institutional barriers to the acquisition of land needed for solid waste management, including land for facilities and disposal sites;

"(9) in consultation with the Secretary of Agriculture, agricultural waste management problems and practices, the extent of reuse and recovery of resources in such wastes, the prospects for improvement, Federal, State, and local regulations governing such practices, and the economic, social, and environmental consequences of such practices; and

"(10) in consultation with the Secretary of the Interior, mining waste management problems, and practices, including an assessment of existing authorities, technologies, and economics, and the environmental and public health consequences of such practices.

"(b) DEMONSTRATION.—The Administrator is also authorized to carry out demonstration projects to test and demonstrate methods and techniques developed pursuant to subsection (a).

"(c) APPLICATION OF OTHER SECTIONS.—Section 8001 (b) and (c) shall be applicable to investigations, studies, and projects carried out under this section.

"GRANTS FOR RESOURCE RECOVERY SYSTEMS AND IMPROVED SOLID WASTE DISPOSAL FACILITIES

86. "SEC. 8006. (a) AUTHORITY.—The Administrator is authorized to make grants pursuant to this section to any State, municipal, or interstate or intermunicipal agency for the demonstration of resource recovery systems or for the construction of new or improved solid waste disposal facilities.

"(b) CONDITIONS.—(1) Any grant under this section for the demonstration of a resource recovery system may be made only if it (A) is consistent with any plans which meet the requirements of subtitle D of this Act; (B) is consistent with the guidelines recommended pursuant to section 1008 of this Act; (C) is designed to provide area-wide resource recovery systems consistent with the purposes of this Act, as determined by the Administrator, pursuant to regulations promulgated under subsection (d) of this section; and (D) provides an equitable system for distributing the costs associated with construction, operation, and maintenance of any resource recovery system among the users of such system.

"(2) The Federal share for any project to which paragraph (1) applies shall not be more than 75 percent.

"(c) LIMITATIONS.—(1) A grant under this section for the construction of a new or improved solid waste disposal facility may be made only if—

"(A) a State or interstate plan for solid waste disposal has been adopted which applies to the area involved, and the facility to be constructed (i) is consistent with such plan, (ii) is included in a comprehensive plan for the area involved which is satisfactory to the Administrator for the purposes of this Act, and (iii) is consistent with the guidelines recommended under section 1008, and

"(B) the project advances the state of the art by applying new and improved techniques in reducing the environmental impact of solid waste disposal, in achieving recovery of energy or resources, or in recycling useful materials.

"(2) The Federal share for any project to which paragraph (1) applies shall be not more than 50 percent in the case of a project serving an area which includes only one municipality, and not more than 75 percent in any other case.

"(d) REGULATIONS.—(1) The Administrator shall promulgate regulations establishing a procedure for awarding grants under this section which— Regulations.

"(A) provides that projects will be carried out in communities of varying sizes, under such conditions as will assist in solving the community waste problems of urban-industrial centers, metropolitan regions, and rural areas, under representative geographic and environmental conditions; and

"(B) provides deadlines for submission of, and action on, grant requests.

(2) In taking action on applications for grants under this section, consideration shall be given by the Administrator (A) to the public benefits to be derived by the construction and the propriety of Federal aid in making such grant; (B) to the extent applicable, to the economic and commercial viability of the project (including contractual arrangements with the private sector to market any resources recovered); (C) to the potential of such project for general application to community solid waste disposal problems; and (D) to the use by the applicant of comprehensive regional or metropolitan area planning.

"(e) ADDITIONAL LIMITATIONS.—A grant under this section—

"(1) may be made only in the amount of the Federal share of (A) the estimated total design and construction costs, plus (B) in the case of a grant to which subsection (b) (1) applies, the first-year operation and maintenance costs;

"(2) may not be provided for land acquisition or (except as otherwise provided in paragraph (1) (B)) for operating or maintenance costs;

"(3) may not be made until the applicant has made provision satisfactory to the Administrator for proper and efficient operation and maintenance of the project (subject to paragraph (1) (B)); and

"(4) may be made subject to such conditions and requirements, in addition to those provided in this section, as the Administrator may require to properly carry out his functions pursuant to this Act.

For purposes of paragraph (1), the non-Federal share may be in any form, including, but not limited to, lands or interests therein needed for the project or personal property or services, the value of which shall be determined by the Administrator.

"(f) SINGLE STATE.—(1) Not more than 15 percent of the total of funds authorized to be appropriated for any fiscal year to carry out this section shall be granted under this section for projects in any one State.

"(2) The Administrator shall prescribe by regulation the manner in which this subsection shall apply to a grant under this section for a project in an area which includes all or part of more than one State. Regulation.

"AUTHORIZATION OF APPROPRIATIONS

"Sec. 8007. There are authorized to be appropriated not to exceed \$35,000,000 for the fiscal year 1978 to carry out the purposes of this subtitle (except for section 8002)." 42 USC 6987.

SOLID WASTE CLEANUP ON FEDERAL LANDS IN ALASKA

dy.
USC 6981
c.

SEC. 3. (a) The President shall direct such executive departments or agencies as he may deem appropriate to conduct a study, in consultation with representatives of the State of Alaska and the appropriate Native organizations, to determine the best overall procedures for removing existing solid waste on Federal lands in Alaska. Such study shall include, but shall not be limited to, a consideration of—

(1) alternative procedures for removing the solid waste in an environmentally safe manner, and

(2) the estimated costs of removing the solid waste.

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mittees.

(b) The President shall submit a report of the results together with appropriate supporting data and such recommendations as he deems desirable to the Committee on Public Works of the Senate and to the Committee on Interstate and Foreign Commerce of the House of Representatives not later than one year after the enactment of the Solid Waste Utilization Act of 1976. The President shall also submit, within six months after the study has been submitted to the committees, recommended administrative actions, procedures, and needed legislation to implement such procedures and the recommendations of the study.

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ndfill, Del.,
chate control
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USC 6981
c.

SEC. 4. (a) In order to demonstrate effective means of dealing with contamination of public water supplies by leachate from abandoned or other landfills, the Administrator of the Environmental Protection Agency is authorized to provide technical and financial assistance for a research program to control leachate from the Llangollen Landfill in New Castle County, Delaware.

peration with
A.

(b) The research program authorized by this section shall be designed by the New Castle County areawide waste treatment management program, in cooperation with the Environmental Protection Agency, to develop methods for controlling leachate contamination from abandoned and other landfills that may be applied at the Llangollen Landfill and at other landfills throughout the Nation. Such research program shall investigate all alternative solutions or corrective actions, including—

(1) hydrogeologic isolation of the landfill combined with the collection and treatment of leachate;

(2) excavation of the refuse, followed by some type of incineration;

(3) excavation and transportation of the refuse to another landfill; and

(4) collection and treatment of contaminated leachate or ground water.

Such research program shall consider the economic, social, and environmental consequences of each such alternative.

(c) The Administrator of the Environmental Protection Agency shall make available personnel of the Agency, including those of the Solid and Hazardous Waste Research Laboratory (Cincinnati, Ohio), and shall arrange for other Federal personnel to be made available, to provide technical assistance and aid in such research. The Administrator may provide up to \$250,000, of the sums appropriated under the Solid Waste Disposal Act, to the New Castle County areawide waste treatment management program to conduct such research, including obtaining consultant services.

USC 6901
c.

(d) In order to prevent further damage to public water supplies during the period of this study, the Administrator of the Environmental Protection Agency shall provide up to \$200,000 in each of fiscal years 1977 and 1978, of the sums appropriated under the Solid Waste Disposal Act for the operating costs of a counter-pumping program to contain the leachate from the Langollen Landfill.

Counter-pumping
program

42 USC 6901
note.

Approved October 21, 1976.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 94-1491 accompanying H.R. 14496 (Comm. on Interstate and Foreign Commerce).

SENATE REPORT No. 94-869 (Comm. on Public Works).

CONGRESSIONAL RECORD, Vol. 122 (1976):

June 30, considered and passed Senate.

Sept. 27, considered and passed House, amended, in lieu of H.R. 14496.

Sept. 30, Senate concurred in House amendments.

WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS, Vol. 12, No. 43:

Oct. 22, Presidential statement.

Note.—A change has been made in the slip law format to provide for one-time preparation of copy to be used for publication of both slip laws and the United States Statutes at Large volumes. Comments from users are invited by the Office of the Federal Register, National Archives and Records Service, Washington, D.C. 20400.

WATER REQUIREMENTS FOR VARIOUS ENERGY PROCESSES

ENERGY SYSTEM

WATER NEEDS

Steam-Electric Nuclear

Evaporative Cooling	17,000 acre-ft/yr/1000mv unit
Pond	12,000 acre-ft/yr/1000mv unit
River	4,000 acre-ft/yr/1000mv unit
Wet-Dry Radiator	2,000 acre-ft/yr/1000mv unit

Steam-Electric Coal

Evaporative Cooling	15,000 acre-ft/yr/1000mv unit
Pond	10,000 acre-ft/yr/1000mv unit
River	3,600 acre-ft/yr/1000mv unit
Dry Radiator	2,000 acre-ft/yr/1000mv unit

Geothermal 48,000 acre-ft/yr/1000mv unit

Natural Gas 50,000 acre-ft/yr for all production in the West

Crude Oil 50,000 acre-ft/yr for all production in the West

Refineries
Oil Shale 39 gal/Bbl/crude
7,600 to 18,900 acre-ft/yr/1000,000 BPD plant

Coal Gasification 8,000 to 45,000 acre-ft/yr/250 million SCF/day plant

Coal Liquification 20,000 to 130,000 acre-ft/yr/1000,000 BPD plant

Coal Slurry Pipeline 20,000 acre-ft/yr/25 million tons coal

Coal Mining
Vegetation reestablishment 5 to 4 acre-ft/acre/yr (some areas may require two years)

Source: Western States Water Council, Water for Western Energy Development Update 1977, Sept 1977, p. 12.

AIR QUALITY

Both federal and state air quality standards must be met at all times during the project. These standards are described in this section.

3.1 FEDERAL REGULATIONS

3.1.1 Ambient Air Quality Standards

Based on the Federal Clean Air act of 1970 (F11), the Environmental Protection Agency (EPA) has promulgated Federal Ambient Air Quality Standards (F12) to limit the concentration of pollutants in ambient air (see Table 3-1). The Federal Clean Air Act specifies that state and local regulations shall not be less stringent; it also requires that significant deterioration of existing air quality be prevented.

3.1.2 Performance Standards

The EPA has also promulgated a series of regulations limiting emissions to the atmosphere from various processes. These regulations are called Federal Standards of Performance for New Stationary Sources, or New Source Performance Standards (NSPS) (F13). In the absence of specific performance standards for oil shale development; three sections of the NSPS may apply to the WRSP:

- o Standards of Performance for Fossil-Fuel-Fired Steam Generators
- o Standards of Performance for Storage Vessels for Petroleum Liquids
- o Standards of Performance for Petroleum Refineries

Performance standards regulating emissions to the atmosphere from power and steam-generating facilities and petroleum liquid storage vessels shall apply if such facilities are installed as part of the project. It is not certain whether petroleum refinery performance standards apply if the raw shale oil is not upgraded. Table 3-2 summarizes the NSPS that govern the proposed facility.

3.1.3 Significant Deterioration

Pursuant to the Clean Air Act, the EPA has promulgated regulations to prevent "significant deterioration" (F14) of air quality in areas in which the air is already cleaner than Federal Secondary Standards require. These regulations focus on particulates and sulfur oxides. At present, litigation is in progress regarding significant deterioration, and the final regulations may differ somewhat from those now in force. Table 3-3 summarizes the existing EPA regulations for allowable increments of pollutants in the three proposed regional classes. It should be emphasized that, as the law presently exists, the EPA-sponsored regulations described in Table 3-3 are the currently enforced scheme for preventing significant deterioration. The area around the U-a and U-b leases is presently designated as Class II.

3.1.4 Lease Regulations

The following paragraphs are part of the terms of the lease (F1):

- o The lessee shall operate all facilities in such a way as to avoid or minimize air pollution and will conduct activities in accordance with all applicable air quality standards. (F1-ES Sec 8A)
- o The lessee shall avoid or minimize causing dust problems. "Where necessary sprinkling, oiling, or other means of dust control will be required on roads and trails. The lessee will conduct processing operations so as not to create environmental or health problems associated with dust." (F1-ES Sec 8B)

Table A-1

FEDERAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Averaging Time	National Standards ^(a)		
		Primary ^(b, c)	Secondary ^(d)	Method of Measurement ^(e)
Photochemical oxidants (corrected for NO ₂)	1 hour	160 µg/m ³ (0.08 ppm) ^(f)	Same as primary standards	Chemiluminescent
Carbon monoxide	8 hours	10 mg/m ³ (9 ppm)	Same as primary standards	Nondispersive infrared spectroscopy
	1 hour	40 mg/m ³ (35 ppm)		
Nitrogen dioxide	Annual average	100 µg/m ³ (0.05 ppm)	Same as primary standards	
Sulfur dioxide	Annual average	30 µg/m ³ (0.03 ppm)	—	Pararosaniline
	24 hours	365 µg/m ³ (0.14 ppm)	—	
	3 hours	—	1,300 µg/m ³ (0.5 ppm)	
Suspended particulate matter	Annual geometric mean	75 µg/m ³	60 µg/m ³	High volume sampling
	24 hours	260 µg/m ³	150 µg/m ³	
Hydrocarbons (corrected for methane)	3 hours (6-9 a. m.)	160 µg/m ³ (0.24 ppm)	Same as primary standards	Flame ionization detection using gas chromatography

- (a) National standards, other than those based on annual averages or annual geometric means, are not to be exceeded more than once per year.
- (b) Concentration expressed first in units which it was promulgated. Equivalent units given in parentheses are based upon a reference temperature of 25°C and a reference pressure of 760 mm of mercury. All measurements of air quality are to be corrected to a reference temperature of 25°C and a reference pressure of 760 mm of Hg (1,013.2 millibar); ppm in this table refers to ppm by volume, or micromoles of pollutant per mole of gas.
- (c) National Primary Standards: The levels of air quality necessary, with an adequate margin of safety, to protect the public health. Each state must attain the primary standards no later than 3 years after that state's implementation plan is approved by the Environmental Protection Agency (EPA).
- (d) National Secondary Standards. The levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant. Each state must attain the secondary standards within a "reasonable time" after implementation plan is approved by the EPA.
- (e) Reference method as described by the EPA. An "equivalent method" of measurement may be used but must have a "consistent relationship to the reference method" to be approved by the EPA.
- (f) Corrected for SO₂ in addition to NO₂.

*Revised 7-16-76

Table A-2

FEDERAL NEW SOURCE PERFORMANCE STANDARDS

Type of Emission	Emission Limits		
	Fossil-Fuel-Fired Boilers	Refineries	Petroleum Storage Vessels
Particulates	Less than 0.10 lb/million Btu input	1.0 lb/1,000 lb of coke burnoff catalytic regenerator	N/A
Sulfur dioxide	Less than 0.80 lb/million million Btu liquid fuel input — less than 1.20 lb/million Btu solid fuel input	Shall not burn any fuel gas in excess of 230 mg/dscm H ₂ S	N/A
Nitrogen oxides	Less than: (a) 0.20 lb/million Btu heat input (0.36 g/million cal.), maximum 2-hour average, expressed as NO ₂ when gaseous fossil fuel is burned (b) 0.30 lb/million Btu heat input (0.54 g/million cal.), maximum 2-hour average, expressed as NO ₂ when liquid fossil fuel is burned (c) 0.70 lb/million Btu heat input (1.26 g/million cal.), maximum 2-hour average, expressed as NO ₂ when solid fossil fuel (except lignite) is burned	N/A	N/A
Carbon monoxide	N/A	0.050% by volume from fluid cat cracking unit	N/A
Hydrocarbons	N/A	N/A	(1) If the true vapor pressure of the petroleum liquid, as stored, is equal to or greater than 78 mm Hg (1.5 psia) but not greater than 570 mm Hg (11.1 psia), the storage vessel shall be equipped with a floating roof, a vapor recovery system, or their equivalents (2) If the true vapor pressure of the petroleum liquid, as stored, is greater than 570 mm Hg (11.1 psia), the storage vessel shall be equipped with a vapor recovery system or its equivalent

Table A-3

LIMITS OF SIGNIFICANT DETERIORATION OF AIR QUALITY

Area Designations		
Pollutant	Class I ($\mu\text{g}/\text{m}^3$)	Class II ($\mu\text{g}/\text{m}^3$)
Particulate matter:		
Annual geometric mean	5	10
24-hour maximum	10	30
Sulfur dioxide:		
Annual arithmetic mean	2	15
24-hour maximum	5	100
3-hour maximum	25	700

- Notes:
1. Class I applies to areas in which practically any change in air quality would be considered significant; Class II applies to areas in which deterioration normally accompanying moderate, well-controlled growth would be considered insignificant; and Class III applies to those areas in which deterioration up to the national standards would be considered insignificant (39 FR 42510).
 2. In areas designated as Class I or Class II, the increases in pollutant concentrations over baseline air quality concentration shall be limited to the values shown above.
 3. All areas of the United States are now designated Class II. Any redesignation shall be determined by the respective states, federal land managers, or Indian governing bodies, subject to approval by the administrator.
 4. In areas designated as Class III, the concentrations of particulate matter and sulfur dioxide shall be no greater than the national ambient air quality standards.

3.1.5 Oil Shale Environmental Advisory Panel Guidelines

A set of air quality guidelines were adopted by the Oil Shale Environmental Advisory Panel (F20). The purpose of these guidelines is to provide the Area Oil Shale Mining Supervisor direction in complying with various regulatory requirements. They also broadly outline the onsite monitoring and control programs necessary for lease compliance and continuing surveillance during facility construction, expansion, and operation.

3.1.6 Vehicular Emission Standards

The EPA has issued emission standards for aboveground vehicles (40 CFR 85). These standards are summarized in Table 3-4. Similarly, the Bureau of Mines* is proposing changes to Schedules 24 (30 CFR #0) and 31 (30 CFR 36) regulating emissions from underground vehicles. The proposed emission standards for underground vehicular emissions include:

- o 6g of carbon monoxide per brake hp per hr
- o 8g of nitrogen oxides per brake hp per hr

3.2 UTAH STATE REGULATIONS

Pursuant to the Utah Air Conservation Act (U8), the Utah State Division of Health, Air Quality Section, has formulated a set of air quality regulations for the state (U9). These regulations incorporate the Federal Ambient Air Quality Standards and New Source Performance Standards as the permissible levels of pollutants to be tolerated. The Utah regulations also made the following control provisions:

*The proposed standards are expected to be enacted by late 1976.
(Telephone conversation with Roger Davis of BM by HCC on Dec. 30, 1975.

Table A-4

FEDERAL VEHICULAR EMISSION STANDARDS

Vehicle		Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	Other
Class	Model Year				
Light-duty ^(a) gasoline-fueled trucks	1975+	2.0 g/veh. mi	20 g/veh. mi	3.1 g/veh. mi	—
Heavy-duty ^(b) gasoline-fueled trucks	1974+	16 g/bhp hr	40 g/ ^(c) bhp hr	(c)	—
Light-duty ^(a) diesel-fueled trucks	1975+	2.0 g/veh. mi	20 g/veh. mi	3.1 g/veh. mi	—
Heavy-duty ^(b) diesel-fueled trucks	1974+	16 g/bhp hr ^(c)	40 g/bhp hr	(c)	20% opacity during acceleration mode 15% opacity during lugging mode 50% peak

- (a) Light duty ≤6,000 pounds of gross vehicle weight
 (b) Heavy duty >6,000 pounds of gross vehicle weight
 (c) Total of hydrocarbons plus nitrogen oxides (as NO₂)

*Revised 7-16-76

"In all areas of the State, air pollution control equipment and processes shall be selected and operated so as to afford the highest efficiencies and the lowest discharge rates that are reasonable and practicable. . ." (U9-Sec 1.7).

This paragraph, nonspecific in terms of types and quantities of pollutants, implies that all potential sources be controlled by state-of-the-art best practical control techniques.

Additionally, maximum control devices are required in areas of the state where the air quality is presently better than the limits:

"In areas of present high air quality where measured or estimated ambient levels of controllable pollutants are below the levels specified by applicable standards, any emission of pollutant to the ambient air must be shown to result in pollution levels. . . within applicable ambient air standards, and will be prohibited in any case unless shown to be fully controlled to afford the highest efficiencies and the lowest discharge rates that are reasonable and practicable. . ." (U9-Sec 1.3).

Source: White River Shale Project

APPENDIX B

**OIL SHALE AND THE ENVIRONMENT
RESEARCH AND DEVELOPMENT**

OIL SHALE AND THE ENVIRONMENT

Greenville, Colorado, September 1988

In 1978, ten years ago, they came to get the shale out--began to, at least. They built a half dozen oil shale plants, then started mining and retorting it a couple of years later.

Since then, Greenville has never been the same. Not that we expected it would be. Before any of it happened there were dozens of reports that tried to define what oil shale would bring to. . .and take from. . . life in Greenville.

In the old days, before the mining began, it was still possible to talk about Greenville without having to talk about shale. Today, Greenville is oil shale. And oil shale is Greenville's environment--air, water, land and life.

So, fortunately, a lot of thinking went into it. Because if it hadn't. . .

WHO IS WATCHING OUT FOR THE ENVIRONMENT?

Everybody. The Environmental Protection Agency, the Department of Energy, other governmental agencies, industry, and public action groups.

Everyone knows that an oil shale industry will cause some environmental changes--changes that could be disagreeable, even dangerous.

EPA is studying many aspects of oil shale development. These studies are developed by EPA through funding provided by the Interagency Energy/ Environment Research and Development Program to obtain information on health and ecological effects from pollutants created by the development. EPA is also developing information on methods that can be used to control the release of those pollutants. The purpose of these studies is to ensure that an oil shale industry will have the fewest possible adverse environmental effects.

As yet, however, there remain a number of unanswered environmental questions. And it may not be possible to satisfactorily answer the questions until an operating plant exists. The technologies are just too new, the affected ecologies are not well-understood, and the scale of operations just too massive to be able to predict with any certainty what effects an oil shale industry will really produce. Also, environmental controls for the oil shale industry are subject to large uncertainties. Simple extrapolation from existing controls may be insufficient for oil shale or may not, for a host of engineering reasons, work with efficiencies required to meet federal and state standards.

In addition to EPA, sixteen other federal agencies are studying oil shale development--both processes and environmental controls--through the Interagency Program. Industry, too, is developing production methods with an eye toward reducing adverse environmental effects. Public action groups are also contributing information on potential areas of disruptive effects.

Often there is overlap in this research and development. While this overlap may involve some duplication of effort, it does offer the advantage that all those who will have a hand in the production of shale oil or who will be affected by the production processes are being made more aware of each other's interests. Out of this awareness can come the solutions to the many problems associated with an oil shale industry. This will allow the industry to develop in an economically and environmentally sound fashion with the best and most practicable technology.

This approach is relatively new in the energy business. In the past, little thought was generally given to the adverse effects of energy development. In this respect, oil shale development may set the practice for future energy development. Since oil shale is the liquid energy resource closest to commercialization, it will be the first to have been so thoroughly environmentally studied before it becomes established as an industry.

HOW WILL GETTING THE OIL OUT AFFECT THE ENVIRONMENT?

In four potentially adverse ways.

- By creating air, water, and solid waste pollution.
- By creating possible hazardous health effects.
- By disrupting the land.
- By creating boom towns with their stressing side effects.

GREENVILLE, COLORADO, September 1988

Oil shale is Greenville's air. Not what it used to be, but still pretty good. After all, there were standards to be met, state and federal, and the industry worked to meet them with all due speed.

Which is not to say that in those early development years, when standards couldn't be met, when we first saw that film of dust on the cars we parked on the street, or when our eyes would smart from fumes from the retorting, that we were not dubious. Mad, in fact. Furious.

But they worked it out like they said they would, and now, except for those rare times when one of the stack scrubbers goes on the fritz, the air is good. Not as good as it used to be, but better than the air in New York City, Los Angeles, or even Lake Tahoe, California. But it's just not the old Greenville air.

WHAT ABOUT OIL SHALE AND AIR POLLUTION?

Currently, the air in the tri-state western oil shale region is relatively clean. But this relatively clean quality of the air is expected to decline somewhat in the long term as a mature oil shale industry becomes rooted in the region. It can also be expected that some people in the area may be affected by the local concentration of air pollution caused by the temperature inversions that frequently occur, especially in Colorado.

In an oil shale industry air pollution will come from a large number of sources, but basically the pollution will be in the form of dust and larger particulates, and gases containing sulfur, nitrogen oxides, carbon monoxide, and trace hydrocarbons.

What About Dust?

There will be dust and larger particulates in the air from blasting, from mining, and from crushing the source shale and transporting it. There will also be dust as a byproduct of hauling the enormous amounts of spent shale from the retorting area to the storage sites, some of which could be miles away.

To minimize the amount of air pollution resulting from dust and larger particulates, a number of major steps will be taken.

In all mining operations, wetting agents will be mixed with water, thus holding down dust during drilling, after blasting, and along the routes that take the shale out of the mine.

In the crushing and retorting plants, the shale will be carried along in covered conveyors and sprayed with water at points where it is to be transferred from these conveyors to processing units. Baghouse filters similar to those used in industrial smokestacks will be used in crusher units to capture the dust from the shale as it is being pulverized. Wet scrubbers will control any particulates generated in retorting operations. Then sprays of water will be used to cut down dust during the transport and stockpiling of spent shale at disposal sites.

Applied conscientiously, these steps should in great measure reduce most of the dust and large particulates that would be potential hazards to air quality in a modern oil shale operation.

What About Gases?

Gases will enter the air from retorting and refining operations and from electric power generation. There will also be emissions to the air from vehicles of all sorts--trucks, earthmoving equipment, workers' automobiles, as well as from commercial developments that will spring up to serve the new urban populace. It is expected that there will be increased haze and lowered visibility in the area. In addition to taking some toll on the quality of the air humans will breathe, air emissions could cause cumulative adverse effects on local vegetation and wildlife.

As with dust and dust control, numerous preventive measures and controls can greatly diminish the danger posed by gases released into the air as byproducts of the oil shale processes.

Sulfur emissions from all gaseous fuels produced in the retorting process will first be treated to recover ammonia and will then be desulfurized before being used to heat the shale. Well-established techniques will be used to remove the sulfur from the retorting and output gases--a Stretford chemical recovery system will be used for the low-Btu gases produced in the Paraho process, and the high Btu gases that are produced by the TOSCO process will be reacted with hydrogen, followed by chemical removal methods, to clean out most of the remaining sulfur.

Diesel equipment used in underground mining will be equipped with devices to reduce particulates and nitrogen oxide emissions in the exhaust.

How well nitrogen oxides emitted from gases produced in shale oil processing are controlled will depend on how much of the nitrogen in the shale can be converted to ammonia before the gases are used as power

plant fuel. Additionally, burners that use the gas for fuel will be designed to reduce nitrogen oxide emissions. If liquid fuels are used in shale processing, they will be reacted with hydrogen to transform their nitrogen content to ammonia before they are burned.

The amount of trace hydrocarbons and carbon monoxide given off to the air from oil shale operations is expected to be within state and federal standards. If there is any question of their quantity, the gas streams in which they are contained will be incinerated before being emitted to the atmosphere. Likewise, trace elements, like arsenic and antimony, are not expected to be emitted from plant gases in large enough quantities to become a hazard.

How Much Air Pollution?

Enough to worry about. The amount of pollutants emitted to the air from retorting operations will vary among the different processes.

In a full-scale industry, several types of processes will be in operation at one time, centered near the sources of shale. Pilot plants used to test these processes now operate under variances to air quality standards granted by federal and state agencies. Emissions from commercial-sized plants, of course, will have to meet air quality standards, and ways to reduce emissions are being studied. But at present none of the processes being considered for a commercial-sized oil shale industry can meet both federal air quality standards and those in force in Colorado.

GREENVILLE, COLORADO, September 1988

Oil shale is Greenville's water what there is of it. And there never was all that much to begin with. What there was came from the Colorado River and its tributaries, the Green, White, and Roaring Fork Rivers, as well as from underground sources and surface streams.

Oil shale took the water, sometimes as much as three barrels of water for every barrel of shale oil, and while no one ever died of thirst in Greenville, there were some rough times for ranchers. One summer, in the early 1980s, there was a real drought, and the cattle suffered. Some ranchers went out of business. But it was a fluke year to begin with, half the normal precipitation, very dry. Still, without oil shale, it might have been a different story. It could happen again, of course, but probably it won't, mostly because almost all of the ranchers sold their land to the oil companies and moved out.

Lucky for Greenville that there was enough advance planning in the late 1970s to assure that all this water, after it had been used for processing the shale, would go to good, safe use which it did. It's been recycled and reused in the processing, again and again. Or, it's been used to irrigate the new vegetation that the companies planted on the huge mounds of spent shale that built up in the area over the years.

Still, I think I feel a little less comfortable each time I go to the tap for a cold drink on hot summer days.

WHAT ABOUT OIL SHALE AND WATER?

The water question has two parts. What will withdrawal of the large amounts of water necessary for extracting and processing oil shale do to local supplies?

And, what kind and how much water contamination will an industry and its associated towns cause?

Supply - Is There Enough?

People disagree about how much water a 1-million bbl/day oil shale industry and its associated towns will use. One estimate by the U.S. Department of the Interior is 120,000 to 190,000 acre-ft per year. This is about 2 to 3 barrels of water for every barrel of oil produced by aboveground retorting. Another estimate by the Colorado Water Conservation Board is 230,000 to 250,000 acre-ft per year. If nahcolite and dawsonite are recovered along with the shale oil, another 50,000 acre-ft will be consumed.

Water for an oil shale industry will be taken mainly from the rivers of the region. Although much of the water in these rivers is already allocated by law to other consumers under the Colorado River Compact of 1922, the Upper Colorado River Basin Compact of 1948, and the Mexico Treaty of 1944, the U.S. Department of Interior projects that there will be ample surface water potentially available for a 1-million bbl/day oil shale industry.

Some people have looked into the alternative of using groundwater locked in underground strata (aquifers) to satisfy an oil shale industry's water needs. One estimate puts the total volume of water stored in aquifers at about 10 million acre-ft, enough to supply a 1-million bbl/day industry for 50 years.

The U.S. Geological Survey estimates that oil shale operations will consume less water for a given amount of energy output than other existing and emerging energy production processes. However, whether water is taken from surface streams or underground aquifers, there is concern about the effects of depletion, and the disruption of streambeds and underground water-bearing strata caused by mining, well-drilling, and spent shale storage. And, among some experts, there is also concern about the long-term availability of water as an oil shale industry expands.

Salinity: When Oil Shale Drinks, What Suffers?

Heavy depletion increases the salinity of surface streams. The U.S. Department of the Interior estimates that a shale oil industry using 120,000 to 190,000 acre-ft of water a year would increase the salinity of the Colorado River downstream at Hoover Dam by 10 to 15 milligrams per liter. But the Colorado River is already heavily salt-laden from withdrawal of water for agricultural use, and desalinization plants are being built on the lower Colorado River so that the water obligated to Mexico will be of the quality specified by treaty. Some of the groundwater in shale country is as salty as seawater, and, if it were used in oil shale operations, it could be highly corrosive to metal parts. Furthermore, saline aquifers disrupted by mining activity could release salt into pure water aquifers adjacent to some of the richest

oil shale deposits. Moreover, saline aquifers punctured by mining activities could flood the mines, making continuous pumping necessary and creating the problem of disposing of brackish water in an environmentally acceptable fashion. As yet, the groundwater consequences cannot be estimated with any accuracy since so little is known about the aquifers and the general groundwater flow patterns.

Water Contamination: With Oil Shale's Gain, What Losses?

Potential contamination of water supplies has implications not only for human, agricultural, and industrial use, but it could threaten the habitat of wildlife and aquatic species. The large herds of migratory mule deer and antelope and elk, as well as birds and water species, could be adversely affected by a reduced supply of water or the contamination of their watering places in the semi-arid regions of Colorado, Utah, and Wyoming.

The enormous amount of water used in oil shale operations will inevitably become contaminated--from retorting the shale and upgrading the product oil, from controlling emissions of pollutants to the air, from cooling processing units and spent shale, from boiler blowdown, and from sanitary facilities. Contaminants will be toxic chemicals, minerals, and trace metals.

The water released from the oil shale itself in the retorting process is contaminated with ammonia, chlorine, carbonates, sulfates, mercury, selenium and arsenic and various organics such as phenols and carboxylic acids. The amount of this contaminated water is 2 to 5 gallons per tone of shale.

Retorting processes being developed incorporate ways to treat this wastewater to rid it of contaminants. In a typical plant, wastewater will be cleansed using a series of methods--a foul water stripping system to remove dissolved hydrogen sulfide and ammonia, a holding pond and gravity separation unit to separate solid contaminants, and chemical additives.

Cleaned up wastewater will be recycled through the process stream so that there will be zero discharge of harmful effluents into surface streams and ground water supplies. Moreover, recycling would reduce consumption by 10,000 to 40,000 acre-ft per year.

Wastewater from mine dewatering, boiler blowdown, and cooling towers will be used directly, without treatment, to suppress dust or wet down retorted shale.

All of these measures apply to mining and aboveground retorting. In situ retorting presents a more severe problem because of the difficulty of controlling the large amounts of wastewater that will result from underground operations.

Some disposal methods being considered for in situ processing are to channel the wastewater into the piles of retorted shale left in the ground, to pump it into aquifers that are already heavily salt loaded, or to let it collect in large evaporation ponds. However, none of these methods is totally satisfactory, and the problem remains to be solved for in situ processes.

The potentially far-ranging effects of water pollution from the various oil shale processes means that keen examination of all the potential hazards must be made and factors carefully weighed before the shale industry develops.

GREENVILLE, COLORADO, September 1988

The first thing I remember hearing about oil shale was that the rock would expand like popcorn when they pulled it out of the ground and took the oil out. But, the experts assured us that this wasn't only the case with oil shale. The fact of the matter was, anything that's mined by breaking it up into smaller pieces expands; more surface area.

What it finally meant for oil shale, after all the explaining was over and the dust literally settled down, was a lot of rock--tons of the stuff--left over. The oil companies called it spent shale. The environmentalists called it solid waste. We had another name for it . . .

WHAT ABOUT OIL SHALE AND SOLID WASTE?

There will be a lot of it. Solid waste from oil shale takes three different forms:

- Fine particles of raw shale produced in crushing operations.
- Catalysts from refining processes if refining is performed in the area.
- Spent shale that remains after the oil is removed.

Particles

One form will be the fine particles of raw shale produced in crushing operations. For example, the Paraho process uses fairly large chunks of raw shale (about 3 inches). In crushing the shale to this size, about 5% to 10% is left over as granules too small to be retorted. Some of these small pieces of shale could be fused to form briquettes that are the right size for retorting. The remainder will be mixed with the spent shale for disposal. But inevitably some finer particles will reach the air to contribute to air pollution.

Spent catalysts

Subjecting shale oil to intermediate refining near the site of retorting operations could produce another type of solid waste spent catalysts. Nickel and cobalt residues used in hydrogen-treating the oil will be left behind, as well as other substances used in recovering sulfur and removing arsenic from the oil. These catalysts, contaminated with potentially harmful compounds, could pollute the air and water if their disposal is not carefully controlled.

If intermediate refining is carried out on site, spent catalysts and deactivated carbon used in removing contaminants from the product gas will be discarded in the spent shale storage areas.

Spent shale potentially dangerous leftovers

The greatest environmental roadblock to oil shale development is the disposal of spent shale. The potential effects of the enormous amount of spent shale cross all major environmental boundaries.

A 1-million bbl/day oil shale industry using high grade (30 gallons per ton) shale will generate 1.5 million tons of spent shale a day. This is after mining, crushing, and retorting. Mining and crushing operations decrease the density and thus increase the original volume of rock by as much as 30% to 40%--retorting shrinks the shale somewhat, but the volume left after retorting is still substantially more than was mined.

Spent shale will vary in consistency, depending on the retorting process, from a lumpy ash-like material resembling dry chunky peanut butter to a fine ash-like substance with a carbon residue that looks like grey talcum powder.

Spent shale will contain potentially harmful amounts of mineral salts as well as toxic trace metals.

Spent shale stored on the surface could interrupt water courses, destroy grazing land and the natural habitat of animal and aquatic species. Stored on the surface or underground it will be subject to leaching and erosion. Contamination from leaching and erosion could have widespread adverse effects on local use of water by industry, by residents, by wildlife and aquatic species in the region, and on downstream water quality as the contamination reached the major river systems.

And, if it is stored on the surface, it will mar the natural beauty of the countryside. For emphasis, people point to the miles of naked rock piles thrown up on the banks of the Blue River near Breckenridge, Colorado, by gold dredges in the 1890s that remain as an eyesore today.

Current plans call for spent shale to be stored mainly on the surface, much of it in gullies and canyons. Control measures have been worked out to reduce the possibility of leaching and erosion of spent shale stored on the surface.

After retorting, the hot shale, which will contain 3% to 5% carbon, will be sprayed with water to cool it and control dust. It will then be transported by conveyor belt or truck to the disposal site. Here, the spent shale will be piled to a specified height. As the pile is developed, it will be graded, and then compacted to a density of 80-90 lbs/cu ft. Compaction will give the pile stability and will slow down weathering. It will also retard leaching since spent shale is highly absorptive and, once compacted, percolation of contaminants through it is minimal. The slope of the sides of the pile will be no greater than a three-or four-to-one grade to prevent sliding.

A catchment basin will be built downstream from the spent shale pile to control leaching and runoff caused by rain or snow, and an impervious layer of material will be laid down beneath the pile to prevent groundwater contamination. Any runoff will be returned to the pile to keep it moist. Likewise, if the spent shale is stored in a canyon, a 100-year flood dam or retention structure will be built above the spent shale to control water flow through the canyon, and a dam will be built below the pile to catch runoff. The water that reaches the lower dam will be recycled back to the spent shale.

When the pile reaches its final height, alkaline salts in the upper layers will be removed. The spent shale will then be fertilized and planted with grazing grass and shrubs that can provide feed for wild herds. Taking out the salts and fertilizing allows for planting directly on the shale, without adding topsoil. The liquid used to remove the salts from the top of the pile will be captured and cleansed to remove contaminants before it is released to the ground.

Experiments in revegetating spent shale have been going on for 10 years, but the composition of spent shale and its lack of nutrients lead many to question the longterm success of any revegetation efforts. For example, will plants now growing on spent shale continue growing after irrigation is stopped? How many plant types will grow on the spent shale? Will the plants tend to concentrate any of the contaminants in the roots and leaves? And what about capillary action that could in time bring salts to the surface of the revegetated shale and destroy the plant growth?

Spent shale also can be returned to the mine, which would help to preserve the scenic quality of the landscape. This is a readily simple process in surface mining since it can be done in conjunction with the return of the overburden to the mined out areas. It could also be returned to an underground mine in its dry form or as a slurried sludge although there are some economic, logistic, and safety constraints to be overcome.

However, spent shale returned to the mine (open pit or underground), or left in the ground after in situ retorting, could pose a greater contamination problem than surface storage because leaching would be more difficult to control.

Clearly, the problem of what to do with spent shale is paramount to the success of the oil shale industry. And it is also clear that the problem has to be dealt with in relationship to air, water, land, and the general look and quality of life in the processing area.

GREENVILLE, COLORADO, September 1988

As for the land, I can't claim that Greenville looks like Ireland these days. But it's important to remember that it wasn't green to begin with. Now, it's actually greener than it used to be. They tore up thousands of acres to get to the shale, then built up hundreds of mounds of spent shale that now cover the countryside. But they planted it, and the large herds of mule deer we were so worried about ten years ago are doing quite well after a few bad years. We've been told that the herd is, at least, maintaining its numbers and we see as many deer as we used to see, along with the other wildlife that live in the region.

But there's no getting around it. The look of the land has changed, but mostly, from what we can tell, everything that survived here for thousands of years, before they came to get the shale, is still surviving.

WHAT ABOUT OIL SHALE AND LAND DISRUPTION?

Count on it. A mature 1-million bbl/day oil shale industry including the towns that develop in the vicinity will occupy about 80,000 acres of land. This amounts to only about 1% of all the oil shale lands that have been explored and evaluated in Colorado, Utah, and Wyoming. The way in which land is disturbed in oil shale development will be similar to that associated with any large mining and/or processing operation. What will be different is the scale of the disruption. Although only a small portion of all of the known shale areas will be affected at one time, a 1-million bbl/day industry will involve mining about 1.8 million tons of oil shale per day.

Mining the oil shale, building roads and plants and towns, and storing spent shale will have a number of local impacts, other than aesthetic. These activities will cause increased erosion and sedimentation, removal or burial of vegetation, and changes in the mix of native trees, shrubs, and grass species. Grazing land will be reduced for range cattle and wild herds.

In the Piceance Basin, development will destroy critical winter range in the river valleys for deer, antelope, and elk in the White and Colorado River regions. The availability of winter range determines the size of the herd that can be supported by the available habitat. Destruction of winter range has a far more severe effect on herd size than similar destruction of the more abundant summer range.

The major environmental disruption in surface mining will be the disturbance of the area being mined and the disposal of large quantities of overburden. Although the overburden will eventually be returned to the mined-out area for reclamation, as much as 2000 acres could be disturbed before any reclamation would take place.

Underground mining will cause the least ecosystem disruption. The major surface disturbance will be the construction of roads for mine access. Properly placed pillars left in the mine will keep severe depressions from developing on the ground surface.

In situ operations would also cause some land disruption: surface subsidence for one. And, since in some in situ processes about 30% of the activity will be carried out at the surface, it shares the same problems of disruption with conventional mining/surface retorting operations.

Land disruption goes with oil shale development, as well as with any other industrial, agricultural, or residential development. But its effects can be minimized by returning disturbed areas as nearly as possible to their natural state. This will require careful, coordinated planning among industry and government, with recognition of the well-being of those who will live and work in the area.

From the Draft Environmental Impact Statement of the Proposed Development of Oil Shale Resources by the Colony Development Operation:

"The proposed Federal action is the consideration of the right-of-way permit for an oil shale products pipeline from a plant site in Colorado to Lisbon Valley, Utah. Directly related to this Federal action is the development of a 4,000 acre underground oil shale mine; mining of 61,000 tons per day of oil shale for 20 years; construction and operation of a 47,000 barrel a day oil shale plant; construction of two dams - Davis Gulch processed oil shale disposal catchment and Middle Fork flood control; disposal of processed oil shale on 800 acres; construction of a 194-mile, 16-inch shale oil pipeline from the plant site on Roan Plateau to Lisbon Valley, Utah; development of a 15-mile-long service corridor in the Parachute Creek valley; construction of a 75-acre terminal site in Grand Valley; construction of two 230 kv powerlines to the plant site; a 337-acre exchange of land between BLM and Colony Development Corporation; and diversion of 12.5 cubic feet per second of water from the Colorado River."

GREENVILLE, COLORADO, September 1988

There were major stories in the mid-1970s about mine safety, about the possible cancer-causing effects of the byproducts of shale mining and retorting. In the ten years since shale came to town, we've had one major mining mishap.

And cancer? The death rate has stayed pretty much what it's been. But there's always next year's figures to worry about - and the year after.

WHAT ABOUT OIL SHALE AND HEALTH EFFECTS?

It is too soon to tell.

There will be the risk of physical injury to workers in the mines and in processing plants, just as there is in any major mining and refining operation. This risk will be minimized by industry compliance with regulations governing such operations. Many of the safety procedures and much of the necessary technical data for estimating the dangers of an oil shale operation can be inferred from other energy industries--coal mining, oil refining.

What is not clear cut is how much of a health hazard air and water pollution from an oil shale industry will pose for humans--those directly involved in shale mining and processing, and those who live nearby. So little is known about the ways in which pollutants are transported through the environment and so little is known about how the human body resists or adapts to different concentrations of pollutants that no realistic estimate can be made of how these effects will ultimately affect the health of the surrounding populace.

There is also concern about a more subtle problem--the potential cancer-causing polycyclical hydrocarbons contained in oil shale. This concern stems from the high incidence of cancer that appeared among British cotton mill workers who had direct contact with spinning machines that were lubricated with shale oil. Workers in the Estonian oil shale industry, however, have no history of occupational cancer. This suggests that only certain types of shale and shale products are potentially carcinogenic.

The danger of exposure to crude shale oil is primarily a localized industrial health problem. Exposure of the general public to refined oil shale products on the commercial market poses a more universal problem. But without a developed American shale industry, it is very difficult to determine what cancercausing risks are to be faced. This entire question is under study by the federal government, the academic sector, and the oil companies.

However, as research into this subject has intensified, it has become clear that there are no good, rapid tests for carcinogenicity. Tests currently used are only approximations to the effects of shale oil on humans and really measure genetic effects. Also, carcinogenicity may only be present when two or more compounds--by themselves not carcinogenic--are combined. Thus, it is not a simple matter of isolating carcinogenic compounds, but of testing the combinations of substances found in the many different products of shale oil.

The cancer question also arises regarding spent shale. The proper management of this waste is particularly important because of the volume

of matter and because spent shale will contain organic compounds with known carcinogenic as well as toxic effects. These hazardous compounds could reach the public via airborne particulates, runoff water, as intake by plants and animals, and as organic vapors. The quantities will probably be small but, as with the refined oil shale products, the health effects are not known. This problem, like the others, is under study to define its severity and its solution.

GREENVILLE, COLORADO, September 1988

Well, the environment suffered and survived, as promised. The money eventually came, as promised, especially to the merchants, the land speculators, the builders. And the jobs came for those who would train for them in industry sponsored programs. And with the jobs, came the salaries, the fringe benefits--life insurance, credit unions, cars, and appliances.

But it all came too fast. In less than two years Greenville was Colorado's largest thriving slum. Shantytowns sprang up and trailers arrived and parked in the middle of open fields. The sewers were anywhere where people dumped their waste. Laundry hung from shanty to shanty, turning black from the early dust.

Greenville's small medical clinic was obsolete in a month. The few diners, restaurants, and markets couldn't stock foodstuffs fast enough. Schools filled to capacity; all the town facilities became woefully inadequate. The government sent us aid money but it was either too little or too late. And they talked a lot about Greenville in the legislature, but not much came of it. They told us we were a boomtown. And I guess we felt about that the way the Indians must have felt when they were told Columbus discovered America. We were hostile, angry, disappointed. We felt disenfranchised. They even dug up our graveyard and made a new one.

Prices skyrocketed--thirty thousand dollars a shanty, two dollars for a dozen eggs. The profiteers ran amuck, everyone tried to sell us something, we locked our doors at night, then locked our doors during the day. The oil shale we had been sitting on for years blew right up in our faces.

But give it time, many said. That was the talk then, for those who decided to stay. So we did. A few years passed, and Greenville finally caught up with the flow of money generated out of our own backyards. A lot of that money stayed in Greenville; a lot more of it came back in the form of federal and state tax revenues. Schools, roads, utilities, hospitals, sewers were built.

Services were upgraded. After the shantytown burned down one night, luckily taking the lives of only the rats that ran through them with abandon, the buildings that went up in their place were solid single-family dwellings that people built to live in, to settle in.

In the early stages of settlement, engineers and middle and upper management would commute from as far away as Aspen, or even Denver, to avoid living in booming Greenville. Now, with better facilities and a stabilized population growth, a number of them are building on a slight rise above the town suddenly called Greenville Heights. There's even a club under construction with a dozen tennis courts and an olympic-sized

pool to be filled, we're told, with recycled water from the plants. And around the pool, no doubt there'll be talk about Greenville culture - once only a picture show, already a music group, a library, and an arts and crafts center, fun by one of the companies for workers and their wives to ease the stresses caused by the crazy boomtown phenomenon.

Now most of those early problems are past. And today in Greenville, population 30,000, we've got new problems, but believe me, they're no longer the problems of a sleepy country town. Nor are they the problems of a wild boomtown. Today they're the problems of any small city in the United States. Plus, we've got oil shale to worry about, and to be thankful for.

WHAT ABOUT OIL SHALE AND BOOMTOWNS?

Almost a certainty.

Development of natural resources in the west has a history of boomtowns. Recent experience in the boomtown phenomenon, and what it causes, comes from Sweetwater and Campbell counties in Wyoming. During this period, the population of these counties doubled - in Gillette, the county seat of Campbell county, the population rose from 3,600 people to 7,200 people.

To put this type of growth into perspective, consider:

- An annual population growth rate of 5% is said by some sociologists to be the maximum tolerable for the timely provision of housing, schools, health facilities and other community services necessary to a population's well being.
- Growth rates between 7% and 10% cause boomtowns that stress services and people alike.
- Beyond a 10% growth rate, the labor market and local government structures often falter and fail to accommodate the new population, which creates chaotic conditions.

Today, about 160,000 people live and work in the tri-state oil shale region. A 1-million bbl/day oil shale industry could double that population. An initial 250,000 bbl/day industry will create 13,000 new jobs - in construction, mining, trucking, and retorting and refining trades. This would draw about 35,000 people to the region, with the bulk of the new population finding employment in new commercial enterprises established to serve the communities that develop around the industry.

What happens in boomtowns?

New jobs and high wages offer a bright outlook, but there is a painful tradeoff - the cost of living curves sharply upward, particularly in housing - especially rental units. As new people arrive, available housing quickly dwindles. Trailer towns and shanties spring up on the fringes of older communities, often with no water or sewage facilities.

Shortages of supplies develop in all areas. Food and recreation prices rise as a result, but salaries of local, old-time residents do

not. For these people, prosperity is a price, not a larger paycheck. Discontent among long-term residents and resentment of newcomers flare to disrupt community spirit and cohesiveness.

As the boom accelerates, those who think it will be temporary worry about a bust. This means that investment in local businesses lags, creating unemployment and making it difficult to entice new employees into crafts and professions. Boom-inflated wages draw workers out of municipal jobs to industrial jobs, which also leaves an employment vacuum.

Health cases overload local hospitals, and new types of health problems appear, most of them psychological, fostered by the stresses that go along with boomtowns leading to alcoholism, broken homes, school dropouts, and down and outs. These factors lead to personnel problems in the new industry and in local business causing high employee turnover and lowered productivity.

Can boomtowns be avoided?

Well, maybe.

But it will take thoughtful planning, money to carry out the plans, and most important of all, perhaps, it will take the wholehearted support of those who live in the shale country.

A 1-million bbl/day oil shale industry plus its urban population will require about \$4 billion over a 10-year period to provide facilities and services to adequately take care of the population influx.

The money needed to provide those facilities and services will come mainly from taxes - local, state and federal. This could amount to a substantial fund that communities could draw on. For example, local tax revenues of \$33 million per year, state revenues of about \$22 million per year, and federal revenues of about \$135 million per year are predicted to accrue from the Department of the Interior's Prototype Oil Shale Leasing Program.

Local communities get much of their revenue from property taxes, but they also receive money through state severance taxes levied on resource developers, reclamation fund taxes, and mining and corporation license taxes.

Different states have different tax money allocation policies. Some money stays in state treasuries, and some is earmarked for specific purposes. States can also require developers to post bond money that can be used for reclamation and to finance expanded services in particular regions.

Federal tax money returns to the development regions in the form of bonus bid money and royalty revenues, general revenue sharing, adverse impact grants, and front-end loans. Under the Mineral Leasing Act of 1920, a certain percentage of bonus bid money from federal leases returns to states in which the leased land is located to be used for schools and roads. In general revenue sharing, a percentage of federal tax revenue can be designated for states that are experiencing adverse impacts of development. States also can apply for adverse impact grants on the basis of demonstrated costs associated with development. And low-cost front-end loans are available to finance public facilities and services needed to keep up with resource development.

Bonus bid money is the money paid to the federal government by the oil companies for the rights to mine oil shale on federal land. It runs into hundreds of millions of dollars.

But, the fact that there are a number of sources of money does not mean that money is always immediately available. Research in the boom areas of Wyoming revealed that there is a 5 to 7-year lag before tax revenues from new industrial and commercial developments are returned to local communities. This puts restrictions on how quickly plans to accommodate accelerated growth can be carried out.

However, guidelines for planning and fund allocation are to be found in the ways in which Wyoming, and more recently Canada, in its tar sands petroleum project, sought means to overcome the stresses caused by resource development. Wyoming has become a model for legislation in western states faced with potential industrial booms to speed up the flow of needed money to areas that will be affected by a surge of population. A key force in alleviating boomtown conditions is the Western Governors Regional Energy Policy Office. This federation of state policy makers has adopted a number of policies aimed at ways to forestall adverse societal impacts of energy development. So, hopefully, by the time an oil shale industry gets under way mechanisms will be there to permit facilities and services to keep pace with growth to sustain an acceptable quality of life.

GREENVILLE, COLORADO, September 1988

At first those of us who lived in Greenville were skeptical when they came finally to get the shale. Skeptical, and just a little scared. Air pollution was a problem, water pollution was a problem. So was solid waste, the look of the land, the health effects of the mining. Living itself seemed to be the biggest problem. But because of what were referred to as "control technologies" in the 1970s, most of these problems have worked themselves out. Or have been worked out by the oil companies, the federal and state governments, and the people of Greenville themselves.

As for the environment, it's impossible to pin down the change. Still, I'd say that we've sacrificed about 10% of what our physical life in Greenville used to be. I might add that our sacrifice was about 30% when it all first began, a surprise to those who spent millions to make sure it wouldn't happen that way. But fair is fair, and though in the midst of the initial crush of new men and machines, it seemed that promises had been made and not kept, those promises are being kept now.

The basic promise, incidentally, was this: America would swap us the "good life" for our shale. It would exact a piece of our environment, but it would be worth the cost.

Though we don't really feel it yet, we are told that because of the significant growth of our population, we are better represented in Washington and in Denver; more important, more and more people listen to Greenville County politicians.

They have to. Because Greenville is oil shale. And oil shale today is a major factor in America's energy market. There is, I'll have to admit, a certain civic pride in that, but more important, there is

something that can't be that easily defined. Call it a feeling, if you like. Today in Greenville, among those of us who stayed for the money and the jobs, there is a feeling that after ten up and down years we finally do have some control over what happens to us. We've been partly led, partly dragged into the mainstream of American industry and power; and even on the individual level, the feeling is there that we are part of the action, on the edge of a special frontier.

So what's Greenville today. Environmentally: it's not what it was. Economically: it's a lot bigger, a lot wealthier. A changed town, one our parents would not recognize, a town that's survived and will, from all indications, continue to survive.

RESEARCH & DEVELOPMENT

It makes sense environmentally, and economically, to develop environmental controls in tandem with oil shale processing technology. This will minimize environmental effects and it will prevent costly retrofits to oil shale facilities once commercial production is under way. This is the rationale for the structure of federally sponsored investigation of oil shale problems.

EPA funds research internally and to other government agencies through the Office of Energy, Minerals and Industry (OEMI). This research is divided into two basic programs: The Process and Effects Program and the Control Technology Program.

The Process and Effects Program looks at:

- Characterizing the types of pollutants that would be expected measuring the magnitude of pollution discharged, and finding ways to monitor and detect the source of those pollutants.
- Tracing what happens to the pollution in the environment. Where does it go? How does it get there? Once it arrives at its final destination, has its form changed to become more or less toxic?
- Defining toxic characteristics. Is human health to be impaired? What part of the body is most susceptible to the types of pollution? What limits must be set to keep hazardous substances out of the environment?
- Determining the effects on the ecologies of the area that are disrupted by the industry. What are the atmospheric and terrestrial ecologies? What are their needs to sustain life? And what will the shale oil development impacts be? Then . . .
- Combining all the consequences of the development into one total integrated assessment for the environment, social and welfare effects, costs/risks/benefits, and selection of alternatives.

In parallel with the Process and Effects Program, EPA Control Technology research evaluates and helps to develop techniques to limit the adverse impacts that shale development could cause. The Control Technology Program is:

- Investigating mining techniques to reduce the adverse effects of the extensive amount of mining that will accompany a commercial oil shale industry.
- Looking at ways to reclaim those areas that have been mined or used for spent shale disposal. This includes the research on revegetation of spent shale piles.
- Assessing the types of the technologies available to control of water, air, and solid wastes.
- Measuring effluents from the retorting processes.

Over \$35 million has been earmarked for oil shale research over the next five years. From \$10 to \$20 million will come from the EPA/ OEMI through the federal Interagency Energy/Environment Research and Development Program.

Not all of the work is being done by EPA scientists or in federal research laboratories. Private industry, universities, and independent research contractors are all part of finding answers to oil shale problems. These research programs cover many areas:

Oil shale and water pollution - about \$3.7 million for research with over 30 different projects.

- Developing a groundwater monitoring model for oil shale and coal mining areas in Utah and Wyoming. By General Electric Company, due in 1971.
- Describing water-related impacts resulting from in situ processes that may prove significant. By the University of California, Berkeley.
- Developing a computer model to predict hydrological effects of oil shale development. By the U.S. Geological Survey, due in 1977.
- Collecting specific hydrologic data in the Upper Basin of the Colorado River, identifying where more data are necessary and developing procedures to assess water quality. By Colorado State University, due in 1977.
- Determining toxicity of material released into the water by oil shale mining and conversion. By Colorado State University, due in 1978.
- Determining leaching rates of inorganic salts from spent shale. By Texas Tech University.
- Developing water control technology for oil shale mining. By Golder Associates, Vancouver, Canada, due in 1977.

Oil Shale and air pollution over \$2.7 million in research funds to more than 20 separate projects.

- Collecting basic atmospheric data for the most likely oil shale development areas. By EPA, due in 1980.
- Establishing quality assurance of air monitoring programs for energy-related work. By Rockwell International, due in 1981.
- Study reaction kinetics of complex organic sulfur and nitrogen compounds in shale oil to design more efficient methods to remove sulfur and nitrogen from shale oil so that when the oil is burned it will need strict air emission standards. By Massachusetts Institute of Technology, due in 1978.
- Identifying the emissions from gasoline produced from oil shale. By Southwest Research Institute.
- Measuring the amounts of particulates, sulfur dioxide, and nitrogen oxides at Rifle, Craig, and Meeker, Colorado. By the State of Colorado, due in 1977.

Oil shale and human health - over 25 research projects with \$3.8 million in federal funds and an additional \$660,000 by industry.

- Studying human health dangers from pilot-plant shale operations. There will be joint U.S. - USSR research to take advantage of the experience in the Estonian oil shale industry. By National Institute for Occupational Safety and Health (NIOSH), due in 1978.
- Finding methods of detecting cell transformations and carcinogenic effects of substances involved in in situ oil shale conversion. By the Lawrence Livermore Laboratory, due in 1977.
- Determining carcinogenic properties of oil shale products and byproducts: interrelated projects cover pulmonary cancer in laboratory animals, upper respiratory problems, epithelial cell damage, changes in lung cell cytology, etc. By EPA and Oak Ridge National Laboratory and Los Alamos Scientific Laboratory, due between 1977 and 1981.
- Developing new testing, screening, and evaluating procedures to assay the carcinogenic and co-carcinogenic potential of oil shale products. By Lawrence Livermore Laboratory and the University of California at Los Angeles, due between 1977 and 1980.
- Studying cell damage and cell recovery from exposure to hazardous oil shale materials. By the Department of Energy, due between 1977 and 1978.
- Determining the chronic inhalation toxicity of shale oil process products. A companion project is studying toxicity from other forms of exposure including oral, ocular, and epidermal. By the American Petroleum Institute.
- Comparing potential carcinogenic effects from oil shale products and alternate energy sources including coal. By EPA and the Department of Energy, due in 1978.

General environmental research for oil shale development -18 separate projects that deal with more than one element of the environment, funded at about \$5.5 million.

- Studying the total environmental impact of oil shale development to compile all background data on industrial processes for oil shale, compare their environmental acceptability, and identify environmental control technologies for air, water, and solid waste emissions. By TRW and Denver Research Institute, due in 1978.
- Assessing the technologies for western energy resource development. This study will develop environmental control policies and strategies for mitigating adverse impacts of western energy sources. By the University of Oklahoma, due in 1978.
- Developing standardized methods for measuring environmental impacts. By the National Bureau of Standards, due in 1979.
- Analyzing environmental control technologies for oil shale development, especially those that have overlapping areas of development. By the University of Utah, due 1977.
- Simulating burning of shale oil in power plants to determine pollutants to be expected from commercial use of oil shale. By Laramie Energy Research Center and Pittsburgh Energy Research Center, due in 1977.

- Assessing the impacts of airborne pollutants from mining and spent shale disposal on forest, range, and freshwater ecosystems. By the U.S. Department of Agriculture, due in 1979.
- Assessing impacts of synthetic liquid fuels development. Examines resources, requirements, net energy analysis, legal mechanisms, financing for the industry, government incentive policies and totally integrated socioeconomic and environmental impacts of oil shale development. By SRI International.

Miscellaneous research - over 40 projects covering such topics as oil shale characteristics and properties, process development, and socioeconomic studies. Almost \$20 million in federal funds are allocated for these projects.

- Performing an integrated assessment of the socioeconomic consequences of coal and oil shale development, including resources used in coal and oil shale industries, in terms of agricultural economic implications and future resource competition. By the U.S. Department of Agriculture, due in 1979.
- Improving methods for converting shale oil to liquid and gaseous fuels and reducing sulfur, nitrogen, and oxygen in the oil as well as to produce pipeline quality gas from an in situ process. By the Department of Energy, due in 1977.
- Demonstrating techniques and economic effectiveness of massive hydraulic fracturing of shale. By the Department of Energy and Columbia Gas System Service Corporation.
- Drilling a bore hole 2350 feet deep in the Piceance Basin for long range experiments in deep mining, and for the extraction of a 500-ton sample of dawsonite-rich shale for testing in an alumina removal project. By the U.S. Bureau of Mines, due in 1977.
- Evaluating methods of producing aviation fuel from oil shale and coal. By the U.S. Air Force and Exxon Research and Engineering.
- Producing 100,000 barrels of shale oil. A series of projects to mine, commission a retort, and an initial plant start-up, and build storage for 80,000 barrels of shale oil. This work will be carried out at the Anvil Points facility and may offer one of the best opportunities to study actual environmental consequences of an operating oil shale plant. By the U.S. Navy and Development Engineering Inc., Grand Junction, Colorado.

Source: U.S. Environmental Protection Agency, Office of Research and Development, Oil Shale and the Environment October 1977, pp. 11-27.

APPENDIX C
OIL SHALE BIBLIOGRAPHY

ECONOMICS
ENVIRONMENTAL IMPACTS
WATER REQUIREMENTS
PRODUCTION TECHNOLOGY
GENERAL INFORMATION

ECONOMICS

. Morgantown, West Virginia. Economic Evaluation
Using 30-gallon Shale and Producing 100,000 Barrels Per Calendar
Day of Shale Oil. (Bureau of Mines, Morgantown, W.Va) Apr
1975. p. 58. of Mines, Morgantown, WV.

An oil shale processing complex consisting of three mines, three retorting plants, and a refinery will require a capital investment of \$1,041,649,000. Included are the equipment installation for mining, retorting, and pipelining gas and crude oil to De Beque, Colo., and the refinery at De Beque. In addition, the cost of chemicals and catalyst, interest during construction (plants), interest during development (mines), startup expenses, and working capital have been taken into account. The complex is designed to process 172,512 tons per stream day or 155,261 tons per calendar day of raw oil shale. Costs used in this report reflect January, 1975 indexes. The total annual operating cost, after taking credit for the ammonia, coke, and sulfur produced as by-products, is \$166,078,000. By-product credits are summarized. Selling price is estimated to be \$8.41 per barrel at a 12% discounted cash flow rate. With the DCF rate at 15% and 20%, the selling price is increased to \$10.07 and \$13.21, respectively. 28 tables, 8 figures.

. Washington, D.C. Oil Shale Technologies. Hearings
Before the Committee on Energy and Natural Resources, United States
Senate, Ninety-Fifth Congress, First Session on S. 419, a Bill to
Test the Commercial, Environmental, and Social Viability of
Various Oil Shale Technologies, and for Other Purposes. Washington,
DC; Committee on Energy and Natural Resources (1977). p. 422.

The hearings on S.419 were conducted to investigate whether or not oil shale is a national asset; they were held in Denver, Colorado on March 11, and Rifle, Colorado March 14, 1977 and in Washington, D.C. April 1 and 28, 1977. Among other things, S.419 sets up a committee to monitor the environmental and social effects of oil shale development. The bill provides for subsidies to communities that are economically and environmentally impacted. Colorado Senator Floyd Haskell, who introduced the bill, presented the opening statement. Fourty-three Statements were heard during the four days of the hearings.

Morgantown, West Virginia. Oil Shale, 1975. An Economic Evaluation Using 30-gallon Shale and Producing 50,000 Barrels Per Calendar Day of Shale Oil. (Bureau of Mines, Morgantown, W.Va.) Apr 1975. p. 59. of Mines, Morgantown, WV.

An oil shale processing complex consisting of a mine, a retorting plant, a solid waste and gas removal plant, and a refinery will require a capital investment of \$567,812,300. Included are the equipment and equipment installation for mining, retorting, pipelining to De Beque, Colo., and the refinery at De Beque. In addition, the cost of chemicals and catalyst, interest during construction (plants), interest during development (mine), startup expenses, and working capital have been taken into account. The complex is designed to process 87,304 tons per stream day or 78,574 tons per calendar day of raw oil shale. Costs are based on January 1975 indexes. The total annual operating cost, after taking credit for the ammonia, coke, and sulfur produced as by-products, is \$93,229,900. By-product credits are summarized. To maintain a discounted cash flow rate of 12%, the selling price of the oil would be \$9.19 per barrel at the plant. 28 tables, 8 figures.

Washington, D.C. Proposed Synthetic Fuels Commercial Demonstration Program: Fact Book. (Energy Research and Development Administration.) March 1976. p. 72.

The proposed program would encourage the private sector to construct and operate "first-of-a-kind" commercial-scale synthetic fuel plants. These initial plants include: shale conversion to synthetic petroleum; coal conversion to gas and clean broiler fuels; and waste conversion to gas, oil and other fuels. The major objectives of the Program are to gain early information and to initiate development of industry infrastructure by: investigating financing, environmental, economic, institutional, technical, and other potential problems, and promoting a limited amount of private sector synthetic fuels experience. Existing and planned domestic energy production would be supplimented by: reducing reliance on imports and providing less expensive energy if world oil prices rise. This fact book provides information on the size and content of the proposed program, its scope and method of implementation as well as a discussion of the potential environmental, socio-economic and other impacts of the program, and the measures recommended to limit their impacts.

Washington, D.C.; Symposium on Oil Shale, Tar Sands, and Related Materials: Production and Utilization of Synfuels. American Chemical Society (1976). p. 315. From American Chemical Society meeting; San Francisco, California, United States of America (USA). (29 Aug 1976).

Twenty-six of the thirty papers presented have been abstracted and indexed individually for ERA/EDB. One of the other four papers has already appeared as UCRL-78098. The three remaining papers were not available for publication.

Adams, R.C., C.E. Banks, W.S. Bradley, L.L. Brannick, and W.G. Christian. Technical and Cost Evaluation of Candidate Large-scale Open-pit Oil Shale Mining Methods in Colorado. Volume II, Parts 1 and 2. Technical and Economic Study of an Integrated Singlepass Mining System for Open-pit Mining of Deep Oil Shale Deposits. Final Report. (Suntech, Inc., Richardson, Tex. (USA)). Jul 1976.

This report describes the feasibility of mining the oil shale deposits of the Piceance Creek basin in Colorado by an integrated open pit system. The study is based upon a comprehensive analysis of pertinent environmental, economic, and engineering factors. Ten mining cases are investigated, and the mine design and cost estimates for each case are presented in this report. Nine of the cases represent three cutoff grades, defining oil shale ore as equal to and above 15 gallons per ton (gpt). 20 gpt, and 25 gpt, at three ore production levels of 500,000 tons per day (TPD), 1,250,000 TPD, and 2,500,000 TPD. The tenth case is an alternate design of the 500,000 TPD production rate at the above 15 gpt cutoff grade. The report consists of Volume I, a technical and cost comparison of the ten cases; Volume II-Part I, a detailed explanation of the estimating methods used; and Volume II-Part 2, a more detailed discussion of the technical and cost features of the ten cases than is presented in Volume I.

Bradshaw, T.F. Bituminous Shales: Their Time Has Come. Rev. Energ.; No. 296, 106-115(Aug 1977).

The complexity and gravity of the energy crisis oblige the USA to start developing all sources of energy. Bituminous shales could represent an important addition to national supplies for several decades since the reserves lying in the Green River bed are abundant and could yield 130,000 million barrels of oil. The report discusses bituminous shale extraction technique, worries respecting environment, socio-economic impact, rise in development costs, restrictions on development caused by legal restraints, and the program of government action which must be drawn up.

Corsentino, J.S. Projects to Expand Fuel Sources in Western States Survey of Planned or Proposed Coal, Oil Shale, Tar Sand, Uranium and Geothermal Supply Expansion Projects, and Related Infrastructure, in States West of the Mississippi River (as of May 1976). (Bureau of Mines, Denver, Colorado. Intermountain Field Operation Center). Sep 1976. p. 222.

This report is a listing of fuels-related projects that are presently under construction, planned, or proposed by various companies and organizations in the Western United States. The future facilities covered fall into the following categories: coal mines and expansions to existing mines, electric power-plants and waste-to-fuel conversion plants, oil shale projects, tar sands projects, potential geothermal facilities, coal slurry pipelines, railroads related to fuels development, uranium mines and enrichment facilities, oil refineries, and natural gas processing plants.

Deering, R.F. Oil Shale Retort Process. (to Union Oil Co. of California). German (FRG). Patent 2,650,189/A. p. 29. 26 May 1977.

In the known processes for the dry distillation of oil shale, the necessary temperatures are produced by part of the oil shale being burnt in the retorts, which has the disadvantage that the waste gas is diluted with air, and thus has no great calorific value for heating. In the proposed process, a preheated circuit gas free of oxygen is used for heating fresh oil shale which is taken to the retorts in counterflow to the oil shale and the shale is moved upwards from below using a mechanical device. This has the disadvantage that the oil vapour produced at the upper, hot end of the retort flows downwards and is therefore not cracked, as it only comes into contact with colder zones. The oil residue leaving the retort at the upper end, which contains considerable amounts of calcite and dolomite, is taken to a combustion zone via a down pipe, where the coke residue is burned off. The flue gas formed in this way is used for heating the circuit gas using heat exchangers. The shale residue from the retort still contains a large proportion of the original sulphur compounds, which form sulphates in the combustion area with the mineral components. If, however, the temperature in the combustion area exceeds a certain upper limit, the SO₂ content in the flue gas rises to impermissible values. The temperature in the combustion area is controlled by diluting the air with the waste gas. This process is not specified in detail.

Dickson, E.M., R.V. Steel, E.E. Hughes, B.L. Walton, and R.A. Zink. Impacts of Synthetic Liquid Fuel Development, Automotive Market. Volume I. Summary. Final Report. (Stanford Research Inst., Menlo Park, Calif(USA). Jun 1976.

This report is the summary report for Volume 2, PB-255995; for abstract, see PB-255995.

Dickson, E.M., R.V. Steele, E.E. Hughes, B.L. Walton, and R.A. Zink. Impacts of Synthetic Liquid Fuel Development, Automotive Market. Volume II. Final Report. Stanford Research Inst., Menlo Park, Calif. Jul 1976.

This study assesses the impacts of the development of synthetic liquid fuels from coal and oil shale; the fuels considered are synthetic crude oils from coal and oil shale and methanol from coal. Key issues examined in detail are the technology and all of its resource requirements, net energy analyses of the technological options, a maximum credible implementation schedule, legal mechanisms for access to coal and oil shale resources, financing of a synthetic liquid fuels industry, decision making in the petroleum industry, government incentive policies, local and national economic impacts, environmental effects of strip mining, urbanization of rural areas, air pollution control, water resources and their availability, and population growth and boomtown effects in previously rural areas.

Donnell, J.R. Global Oil-shale Resources and Costs. (Geological Survey, Denver). pp. 843-856 of In Future supply of nature made petroleum and gas. Meyer, R.F. (ed.). Elmsford, NY; Pergamon press Inc. (1977).

Estimates of global oil shale resources made by various people and organizations are reviewed. Activities on oil shale development around the world are cited. A review of data on the available oil in the shale reveals that the energy source should be developed, but economic considerations favor exploration and development of a conventional crude oil. A barrel of oil from Colorado oil shale averaging about 35 gallons of oil per ton is estimated to cost about \$10 while a barrel of Gulf coast offshore oil costs \$6. Amortization of the initial investment is briefly discussed. 22 references.

Espitalie, J, J.L. Laporte, M. Madec, F. Marquis, P. Leplat, J. Paulet, and A. Boutefeu. Rapid Method for Source Rock Characterization and for Determination of Their Petroleum Potential and Degree of Evolution. Rev. Inst. Fr. Pet. Ann. Combust. Liquides; 32: No. 1, 23-42 (Jan-Feb 1977).

Fundamental research on kerogens by different physiochemical analysis methods have led to the development of a method and equipment suited for petroleum exploration. The development of this method is described and, by means of the parameters, it determines how it can be applied in the yield of petroleum exploration: exploring different types of source rock and their petroleum potential and characterizing their degree of evolution (oil zone/gas zone). This method is also shown to be particularly suited for estimating the oil field of oil shales and investigating the quality and classification of coal. 24 references.

Gardner, G.M. Comparison of Energy Analysis of Oil Shale. 15 Oct 1977. In Energy analysis of models of the United States. Annual report.

A review of seven net energy analyses of proposed and projected oil shale operations showed yield ratios claimed from .68 to 19.8 as compared to 6 for purchase of foreign oil. Because of anticipated heavy instruments for mining, processing, transporting, and for environmental protection and land reclamation, net energy is defined as the energy flow beyond that needed to process the energy where both flows are expressed in equivalents of the same energy quality. Many energy flows were omitted and many possibilities for underestimation and omission of feedback costs exist where the operations are only conjectural. The only analysis of actual operations were less than 1 with no net energy, but the costs for these operations were mainly for research. No satisfactory net energy analysis is yet available that includes all the energy flows of a pilot operation. 28 references.

Gary, J.H. Motor Fuels From Oil Shale: Production and Properties. (Colorado School of Mines, Golden). pp. 136-148 of Future automotive fuels: prospects, performance, and perspective. Colucci, J.M., N.E. Gallopoulos. (eds.). New York; Plenum Publishing Corp. (1977).

The oil shales of Colorado, Wyoming and Utah are not shales and do not contain any liquid oil. The base material is a marlstone, very similar to limestone, which is dense and non-porous. The organic material is a solid called kerogen which does not melt and has very limited solubility in such organic solvents as benzene, acetone and ether. It is necessary to heat the kerogen to temperatures near 900°F to cause the kerogen to decompose and give a liquid shale oil, gases and carbon as products. The organic content of the Western shales is about 14% by weight and, upon pyrolysis, yields from 25 to 40 gallons of oil per ton of rock. There are two general methods for converting the solid kerogen to shale oil: one is by mining and retorting the shale above ground and the other is by establishing communications (introducing porosity) in the shale and retorting the shale underground or in situ. The raw shale oil produced from the retorting is high in unsaturated hydrocarbons, nitrogen and sulfur. In order to produce satisfactory motor fuels more intensive and expensive processing is required than to produce motor fuels from conventional crude oils. Background is presented on shale and shale oil properties, retorting and refining methods and properties of finished motor fuels.

Gutmanis, I, L.S. Guiland, R.A. McBrayer, R.P. McKenna, and A. Paul. Study of Manpower Requirements by Occupation for Alternative Technologies in the Energy-related Industries, United States, 1970 to 1990. Volume II. Part B. (National Planning Association, Washington, D.C. (USA)). August 1974.

Volume I presents direct labor usage coefficients estimated from industry surveys by the National Planning Association for the Federal Energy Administration, covering some sixty different occupations involved in construction and operation and maintenance of energy facilities. Volume II, Part B contains coefficients for the following industries: shale oil, geothermal, construction, pipelines, and marine transportation.

Harrington, W., D. Abbey, and J.W. Sawyer, Jr. Electric Power and Synthetic Fuels Industries in the Southwest: Production and Environmental Control Technologies. (Resources for the Future, Inc., Washington, D.C. (USA)). Aug 1977. p. 229.

This report is concerned with the technologies most likely to be employed in the development of the vast coal and oil shale resources that underlie the arid and mountainous lands of the American Southwest. These technologies--electric power production, gasification and liquefaction of coal, and liquid fuels production from oil shale--evoke a concern with the potential environmental impacts, particularly those relating to water consumption and the

discharge of residuals, and with the extent to which these impacts can be mitigated by the application of control technology. This document focuses on: (1) the chemistry, reserves, and production of coal; (2) technologies for fossil fuels--electric power production, energy transportation, synthetic gas, syncrude from coal, and the oil shale industry; (3) control technologies; (4) cooling system functions; and (5) the changing energy picture in the Southwest.

Haycocks, C. Impact of Rising Energy Costs on the Domestic Production of Selected Commodities. (Virginia Polytechnic Inst. and State Univ., Blacksburg (USA)). Division of Minerals Engineering). May 1976. p. 124.

The importance of energy in the future of both the United States' and, indeed, the world's industrial development cannot be over-emphasized. World consumption of energy has increased rapidly in recent years, reflecting the explosion in world industrial capability as well as the increase in standard of living. The purpose of this study is to determine what effect the increased power costs might have on the production of selected commodities in the United States. The commodities selected for study are: bituminous coal, iron and steel, phosphate, copper, and oil shale.

Hoskins, W.N., R.P. Upadhyay, J.B. Bills, C.R. Sandberg III, and F.D. Wright. Technical and Economic Study of Candidate Underground Mining Systems for Deep, Thick Oil Shale Deposits. Final report. (Air Pollution Technology, Inc., San Diego, Calif(USA)). Oct 1976.

This report covers: (1) chamber and pillar mining with spent shale backfill, (2) sublevel stoping with spent shale backfill, (3) sublevel stoping with full subsidence, and (4) block caving mining using LHD's. Final refinement and analysis of these four systems indicated their technical feasibility over at least part of the range of conditions expected in the deeper deposits. Their economic feasibility also was indicated under certain operating and market conditions. A variety of engineering, production, and cost information is provided on each of these systems.

Jatrow, S.N., and W.M. Zykow. Utilization of Bituminous Shales in the USSR. Przegl. Gorn.; 32: No. 5, 190-193(May 1976).

The reserves of bituminous shales in the USSR are discussed together with the actual state of their extraction and utilization as fuel in the power industry and as chemical feedstock. Outlooks for increasing the output of bituminous shales in the USSR from present day 33 million tons to 160 million tons per year in 1990 are given, including the technical aims leading to the increase in economic effectiveness of processing this raw material.

Karlinger, M.R. Economic Worth of Hydrologic Data in Project Design: an Application to Regional Energy Development. (Geological Survey Reston, Va. (USA). p. 63.

The linkage between the benefits to regional economy from a water-dependent industry and the statistical uncertainty of the water supply that is needed in the production process is analyzed using a Bayesian scheme of expected-expected benefits of hydrologic data. In this analysis, expected benefits are calculated using anticipated streamflow data and these benefits are averaged over all possible data values. The increase in these average expected benefits is subsequently compared to the costs of obtaining the data and benefits foregone by delaying the project to collect the data. Thus, the value of collecting the data may be determined. A Leontief type production function is assumed for an oil shale retorting plant. The economic impact of hydrologic uncertainty is investigated by examining potential changes in plant output along with changes in regional incomes which are calculated by means of a regional input-output model. Alternatives for reducing the uncertainty included establishing water discharge measuring stations, transferring streamflow information from one site to another via regionalization, and a combination of both. Given a specific alternative, the optimum time period for data collection was found. Regionalization considered statistical properties of network designs based on simulated regression analysis.

Kramers, J.W., and R.A.S. Brown. Survey of Heavy Minerals in the Surface-mineable Area of the Athabasca Oil Sand Deposit. (Alberta Research Council, Edmonton). CIM Bull.: 69: No. 776, 92-99(December 1976).

Samples from seven test wells distributed throughout the surface-mineable area of the Athabasca Oil Sands have been evaluated to determine the amounts of heavy minerals present and the titanium and zirconium contents. The samples were treated to yield the size distribution of the titanium and zirconium minerals as well as their spatial distribution. The study has shown that heavy minerals are found throughout the surface-mineable area; concentrations range from 0.24 to 2.29 percent (by weight), with a mean of 1.02 percent. Titanium and zirconium contents vary throughout the area and are found preferentially in the finer size fractions. On the basis of preliminary calculations, the tailings stream from an oil sands plant would provide sufficient feed for a large-scale titanium pigment plant, and the tailings from one plant would provide sufficient zircon feed to satisfy Canadian demand for metallic zirconium. Variability of the heavy mineral content and composition is such that the heavy mineral potential must be evaluated in detail for each mine site.

Parent, J.D., and H.R. Linden. Survey of United States and Total World Production, Proved Reserves and Remaining Recoverable Resources of Fossil Fuels and Uranium as of December 31, 1975. Chicago; Institute of Gas Technology(1977). p. 50.

IGT's estimates of world and U.S. proved reserves and remaining recoverable resources are given. In no case should current resource estimates be considered final, since production, exploration and development cause continuous changes. Exploration has been very uneven geographically. The values assigned to proved reserves and potential additional resources depend on technological and economic consideration as well as on physical characteristics and sizes of the deposits. The currently significantly increasing wellhead prices of gas and oil and of coal prices at the mines should lead to appreciably enhanced economic incentives to explore and produce and, thereby, to significant increases in recoverability of deposits in place and to increase discovery rates. The U.S. proved and currently recoverable fossil-fuel energy reserves amounted to 5.64 Q, (10^{18} Btu). This compares favorably to the world figure of 20.9 to 21. Q. The estimated U.S. total remaining recoverable fossil-fuel energy resources of 28.6 to 45.6 Q compare roughly proportionally to the world total of 107.5 to 122.5 Q.

Lukachinski, J., and R.G. Tessmer, Jr. 1985 Technical Coefficients for Inputs to Energy Technologies. (Brookhaven National Lab., Upton, New York. (USA)). Jun 1976.

This report describes the incorporation of input-output technical coefficients for five new energy supply and conversion technologies as estimated by the MITRE Corporation into a 110-sector Energy I-O Model. The five new technologies are solvent refining of coal, oil shale mining and retorting, high-temperature gas-cooled reactor electricity generation, high-BTU coal gasification, and COGAS combined-cycle electricity generation. Incorporation of seven existing energy supply and conversion technologies is also described: crude oil and gas extraction, coal mining, refined petroleum products, pipeline gas, fossil electric generation, and hydroelectric generation. Non-energy input coefficients are given in units of 1967 $\$/10^6$ BTU and represent the inputs in constant 1967 dollars from non-energy sectors (e.g. manufacturing, transportation, services) required per 10^6 BTU of energy production by each of these energy supply technologies. The 90 non-energy sectors included are based on the Bureau of Economic Analysis 83 sector input-output structure for 1967 with minor disaggregations. Energy input coefficients are given in units of BTU/BTU.

Maddox, K.P. Net Energy Analysis of Oil Shale Systems. (Colorado School of Mines Research Inst., Golden). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 21: No. 6, 18-24(1976).

As part of a larger Colorado Energy Research Institute study of western-based fossil fuel production systems, a net energy analysis of oil shale was conducted. Complete energy characteristics (unrecovered resource, process losses, and "imports" from other energy-producing systems) for oil shale systems producing liquid fuel and electricity were examined in detail. The methodology of net energy analysis is summarized, the results for three oil shale processes are presented, and oil shale systems are compared to conventional petroleum systems. In addition, some conclusions concerning the net energy potential of oil shale systems are drawn. Finally, the utility of net energy analysis as a tool for decision-making is discussed.

Marland, G. Net Energy Analysis of In Situ Oil Shale Processing. (Institute for Energy Analysis, Oak Ridge, Tenn. (USA)). Feb 1977.

Although the domestic resources of shale oil are large, there has been some question regarding the magnitude of the energy subsidy that must be committed in order to extract the contained oil. This study shows that for a 50,000-barrel-per-day, modified in situ extraction facility in 20-gallon-per-ton Green River shale, the energy yield is about 8.6 times the energy subsidy and that about 21 percent of the in-place oil can be thus recovered. If the mined-out shale is retorted at the surface rather than being discarded, the recovery factor rises to 37 percent and the net energy ration should rise significantly as well. It is different to compare these figures with those for aboveground retorts because oil burned in place for retorting never enters the energy accounts. However, the resource commitment per unit of recovered energy is more easily compared and is essentially indicated by the reciprocal of the recovery fraction.

Miknis, F.P., A.W. Decora, and G.L. Cook. Pulsed NMR Examination of Oil Shales: Estimation of Potential Oil Yields. (Laramie Energy Research Center, WY). pp. 35-45 of In Science and technology of oil shale. Yen, T.F. (ed.). Ann Arbor: Ann Arbor Science Publishers Inc. (1976).

Two groups of oil shale samples from two different cores were by-pulsed NMR in a routine assay-type operation. In cores for which adsorbed water was a contributor to the NMR signal, it was necessary to make two NMR measurements of the free induction decay amplitude to correct for this interference. Statistical analyses are presented to show that the NMR data correlate linearly with Fischer assay oil yield data.

Montgomery, D. Commercialization of Synthetic Fuels: Alternative Loan Guarantee and Price Support Programs. Background Paper No. 3. (Congressional Budget Office, Washington, D.C. (USA)). 16 Jan 1976. p. 40.

The analysis provides background information about incentives for the development of commercial-scale synthetic fuels from coal, oil shale, and other sources, specifically urban wastes. With the President proposing a program to bring these programs into commercial production in the near future, price supports, loan guarantees, and construction grants were designed. The proposals and decisions facing Congress are discussed. Criteria for decisions include: is there a need for synthetic fuel production; will private industry proceed without Federal intervention; what is the best mix of incentives; are the costs of the proposed incentives acceptable; and what are the technology mixes, the program levels necessary, the environmental considerations, and the employment impact. Discussions on the potential impact on the Federal budget and the timing of decision conclude the report.

Mutschler, P.H., J.J. Hill, and B.B. Williams. Uranium From the Chattanooga Shale: Some Problems Involved in Development. (Bureau of Mines, Pittsburgh, Pa. (USA). Eastern Field Operation Center-Field and Environmental Activities). 1976. p. 89. Bureau of Mines, Washington, D.C.

Chattanooga shale was studied to determine the quantity and quality of the uranium resources present and to assess specific environmental effects of mining the shale. Geologic data and chemical analyses, mainly concerning a 12-county area of Tennessee, were compiled from previous published and unpublished reports. Uranium resources in the Gassaway Member of the Chattanooga Shale Formation in this 12-county area were estimated to be between 4.2 and 5.1 million tons, contained in 76 to 91 billion tons of shale. These figures represent inground tonnages and do not allow for mining or processing losses. Depending upon efficiency of mining and processing systems, enough uranium could be available to satisfy a large part of the cumulative domestic and world demand through the year 2000. A model was developed which assesses the total tons or acres of shale to be mined if the Gassaway Member were to satisfy 1 percent of the United States demand for uranium in 1991. This partially demonstrates the environmental impact of mining the shale and is easily factorable to any specified demand.

Oliver, E.D., and A.J. Moll. Preliminary Feasibility Studies in Times of Rapid Cost Escalation. (Stanford Research Inst., Menlo Park, Calif). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 21: No. 6, 1-10(1976).

Not the least of the problems delaying the development and commercialization of synthetic fuel processes has been the extraordinary escalation of cost estimates by factors of up to ten in

the past eight years. This study identifies and analyzes some of the most important contributing factors that have converged in the last few years. These factors include over-optimism and ill-defined project scope in the early stages, tightening environmental controls, difficulties in obtaining raw materials and fuels, general inflationary trends, "hyperinflation" of the costs of critical equipment, local labor shortages, and increased times required for procurement and construction. Cost increases have been particularly dramatic for "offsites," liberally defined as nonprocess related parts of projects. Case histories of oil shale and tar sand developments are analyzed. Learning curves of costs during development and commercial use are studied. The analysis suggests that the worst of the extraordinary increases (above general inflationary trends) are probably over. Criteria to judge the state of development of processes are given, and some procedures to avoid future pitfalls are suggested.

Pforzheimer, H. Paraho: Outlook for Commercial Development. (Paraho Oil Shale Demonstration, Inc., Grand Junction, Colorado). Q. Colo. Sch. Mines: 71: No. 4, 65-70 (Oct 1976).

Operating experience of the Paraho process is reviewed. Recent events, including ERDA's requirement of a second Environmental Impact Statement, have slowed down development of a module program. The need for incentives in the development of an oil shale industry is emphasized.

Prull, P.E. Method for Extracting Oil From Oil Shale. US Patent 4,028,222. 7 Jun 1977.

A method is given for extraction of oil from oil shale in which the shale is first crushed and then classified by a rotating trammel screen into four separate portions of differing longest particle dimension, namely less than 1/4 inch, less than 1/2 inch, less than 3/4 inch and greater than 3/4 inch, with the first three portions being treated while passing through the trammel screen and each portion then separately centrifuged under conditions of centrifuge speed, time and added heat optimal for shale particles of that size. The fourth portion is recrushed. The applied heat may be dry heat, dry steam or wet steam, and the temperature range lies between 200° F and the flash point of the oil to be reextracted from the shale. Pressures ranging from atmospheric to slightly above atmospheric may be applied. 9 claims, 2 figures.

Stout, N.D., G.J. Koskinas, J.H. Raley, S.D. Santor, R.L. Opila, and A.J. Rothman. Pyrolysis of Oil Shale: Effects of Thermal History on Oil Yield. (Lawrence Livermore Lab., Livermore, CA). Q. Colo. Sch. Mines; 71: No. 4, 153-172 (Oct 1976).

The effect of thermal history on the oil yield of a powdered, 22-gallon-per-ton Colorado shale was studied by heating to test temperature at Fischer assay rate (12°C/min), holding at test

temperature for varying times up to 33 days, and finally heating to 500°C at 12°C/min. Test temperatures covered the range of 150 to 450°C. Both autogenous (self-generated) and inert sweep gas atmospheres were used. Under autogenous atmospheres, at test temperatures of 250°C or below, yields obtained were 100 percent of Fischer assay. Heating at 300 to 425°C resulted in yield losses, maximizing at 19 percent after a 33-day exposure at 350°C. Yield losses are accompanied by increased char in the retorted shale and by production of oil that is lower in density and nitrogen content and higher in hydrogen. The inert gas sweep experiments, increasing flow rates, gave increased oil yields approaching 100 percent of assay. This is attributed to reduced thermal degradation of oil in the retort. The total yield appears to be determined by the temperature-time exposure of the liberated oil and is not affected by the thermal history of the kerogen. The results indicate that the high gas sweep rates planned for in situ retorting will be advantageous to oil yield.

Urov, K.E., and A.I. Listrem. Comparative Characteristics of the Organic Matter of Devonian and Jurassic Combustible Shales of the Ukhta Deposit. (Inst of Chem, Acad of Sci of the Est SSR). Solid Fuel Chem. (USSR); 11: No. 2, 65-71(1977).

In the reported experiments, the compositions of the bitumoids and tars from the semi-coking of the combustible shales of the Ukhta deposit have been investigated by chromatographic methods. Questions of the genesis of these shales are discussed. 25 refs.

Utter, S. Advancing Mining Technology of Oil Shale. (Denver Mining Research Center). Q. Colo. Sch. Mines; 71: No. 4, 177-197 (Oct 1976).

Plans and objectives of the U.S. Bureau of Mines' mining programs, including in-house and contract research, are discussed. Results of preliminary core drilling and ground water testing in the Piceance Creek Basin are given.

Weber, J.H. Oil Shale Processing Technology Above Ground and Below Ground. From Symposium on sampling strategy and characterization of potential emissions from synfuel production; Austin, Texas, USA (6 Jun 1976).

A brief review of the oil shale technology is given with application to world distribution, production methods, environmental and economic problems.

Wildung, R.E., T.R. Garland, R.G. Riley, J.D. Silviera, J.E. Rogers, R.M. Bean, and S.W. Li. Terrestrial Effects of Oil Shale Development and Development of Chemical Reactions, Stability and Transport Model of Oil Shale Process Wastes in Soil. Feb 1978.

The search for domestic energy supplies will lead to increased exploitation of domestic fossil fuels. Vast domestic resources of oil shale may provide a long-term alternative to petroleum-derived fuel products. Practical processing experience with shale oil is limited in comparison to other fossil fuel production since serious industry consideration of shale oil production has not been concerted. Methods proposed for winning shale oil from its deposits range from conventional mining and aboveground retorting technologies to in situ combustion methodology. Although the technical and economic aspects of this wide range of options have been generally studied, the environmental impacts must be assessed, as questions of siting, control technology, licensing, and regulation can strongly affect the best production strategy. Preliminary results are reported from studies on the chemical characterization of effluent residuals from oil shale process wastes, their transport through soils, and toxic effects on plants.

Environmental Impacts

. Denver, Colorado. Accomplishment Plan. Region VIII. Comprehensive Energy-Environment Program. (Environmental Protection Agency, Denver, Colorado (USA). Region VIII). Jun 1975.

In 1974 the Region implemented a Northern Great Plains Resources Program effort to address regionwide energy developmental activities and to focus priority attention on the environmental impacts from coal and oil shale activities. This Accomplishment Plan is a continuation of the 1974 and 1975 Accomplishment Plans. Development of other energy sources may have significant environmental impacts. These include oil and gas, tight gas, geothermal, and hydroelectricity. Consistent with Region VIII's prevention posture, the U.S. Environmental Protection Agency has formulated a regional energy-environmental Program.

. Denver, Colorado. Accomplishment Plan. Region VIII. Comprehensive Energy-environment Program. Appendix. (Environmental Protection Agency, Denver, Colo. (USA). Region VIII). Jun 1975.

The appendix to a foregoing report on energy and environmental management contains graphic and tabular data on surface water quality monitoring in coal mining and oil shale operations in the Region VIII states, energy resource utilization, and air quality monitoring.

. Washington, D.C. Alternative Fuels Demonstration Program. Volume I of II. (Energy Research and Development Administration, Washington, D.C. (USA)). Sep 1977. p. 780

While processes for converting coal, oil shale and other domestic resources into synthetic fuels have been known for many years, they have not been applied on a commercial scale in the U.S. because, in the past, the synthetic products were not competitive in cost with petroleum and natural gas. In order to remedy the situation, a program to accelerate alternative fuels production has been proposed. The three major objectives of this program are: To ensure early development of the technical, environmental and economic information and the industry infrastructure needed prior to any possible major expansion of synthetic fuels production capacity; to improve the nation's international position in energy matters; and to increase domestic energy production in the mid-term by supplementing existing and planned domestic energy production. This Environmental Statement examines impacts of the program on a plant-by-plant basis and in the aggregate. To examine aggregate impacts,

four options for total program implementation have been analyzed. This Environmental Statement deals with the potential environmental impacts that could occur as the result of implementing the Alternative Fuels Demonstration Program under each of these strategies. This Environmental Statement uses a "building block" approach to assess the potential environmental impacts of a synthetic fuels industry. This approach allows for assessing the impacts related any combination of production levels, technological mixes and buildup rates.

Washington, D.C. Balanced Program Plan: Analysis for Biomedical and Environmental Research. Volume 5. Oil Shale Technology. (Energy Research and Development Administration, Washington, D.C. (USA). Div. of Biomedical and Environmental Research). Jun 1976.

Oil shale technology has been divided into two sub-technologies: surface processing and in situ processing. Definition of the research programs is essentially an amplification of the five King-Muir categories: (A) pollutants: characterization, measurement, and monitoring; (B) physical and chemical processes and effects; (C) health effects; (D) ecological processes and effects; and (E) integrated assessment. Twenty-three biomedical and environmental research projects are described as to program title, scope, milestones, technology time frame, program unit priority, and estimated program unit cost.

Washington, D.C. Biological Services Program, Fiscal Year 1975. Annual Report No. 1. (Fish and Wildlife Service, Washington, D.C. (USA). Office of Biological Services). Apr 1975. p. 52.

The Biological Services Program was initiated in 1974 as an information bridge between research and field operations within the U.S. Fish and Wildlife Service. Information provided to decision makers aids in accommodating fish and wildlife values in programs associated with energy research and development and land and water development. Project areas include terrestrial habitats and fauna disturbed by oil shale, coal, or geothermal development; freshwater impingments associated with water allocation and stream channelization; and coastal and offshore management. The FY budget for the base program was \$4,412,000 plus \$3,510,000 in funds transferred from other agencies. A directory for 107 staff members is attached.

Washington, D.C. Oil Shale and the Environment. (Environmental Protection Agency, Washington, D.C. (USA). Office of Research and Development). Oct 1977. p. 33.

The environmental effects of oil shale exploitation are evaluated and government actions to ensure that shale development does not become an intolerable environmental burden are discussed. The discussions are presented in sections on the oil shale resource, recovery processes, environmental effects, oil shale research and development, and resource development forecasts.

Madison, Wisconsin, Oil Shale Development in North-western Colorado: Water and Related Land Impacts. Water Resources Management Workshop. (Wisconsin Univ., Madison (USA). Inst. for Environmental Studies). Jul 1975. p. 254.

This study was made to examine the difficulties and benefits of an interdisciplinary inquiry into current and planned oil shale development, to determine and record data pertaining to land and water uses with and without various levels of oil shale extractive technology in the Piceance Creek Basin, and to assist the local and regional governments in the basin in planning for secondary impacts on the social, cultural, and economic framework of the area. 24 figures, 76 tables, 14 maps.

Washington, D.C. Tox-tips. Monthly Report. (National Library of Medicine). 1978. 12 issues.

Toxicological study of inhaled shale materials in rats and monkeys; Carcinogenic potential of oil shale and its process derivatives in mice; Teratogenic potential of benzene in rats; Teratogenic potential of Stoddard solvent in rats; Teratogenic potential of toluene in rats; Teratogenic potential of xylene in rats; Behavioral and physiological effects of microwave exposure in rats; Behavioral effects of 2450 MHz microwave radiation in rats; Effects of 915 MHz microwave radiation in rats; Effects of 2450 MHz microwave radiation in rats; The effects of prenatal exposure to 915 MHz microwave radiation in rats; The effects of prenatal exposure to 2450 MHz microwave radiation in rats; Behavioral effects of 915 MHz microwave radiation in rats; Teratological study of 2450 MHz microwave exposure in mice; Teratogenic study of benzene in mice; Teratogenic study of toluene in mice; Teratogenic study of xylene in mice; Effects of microwaves on immune defense mechanisms in mice; Effects of microwave exposure on immune defense mechanisms in perinatal rats; Teratological study of mice exposed to microwaves; Index of compounds; Index of institutions and investigators.

Maryland, Columbia. Toxic Trace Pollutant Coefficients for Energy Supply and Conversion. Final Report. (Hittman Associates, Inc., Columbia, Md. (USA)). 30 Sep 1977.

The motivation for this study was the recognition by the Energy Research and Development Administration (ERDA) of a need to focus attention on not only the major pollutants but also the toxic tract pollutants from energy supply, conversion and end use activities. This study addresses and quantifies approximately 44 toxic trace air and water pollutants that are generated by energy supply and conversion activities. The study builds upon previous work done by the Council on Environmental Quality, the Environmental Protection Agency and the National Science Foundation. The toxic trace pollutant data base generated by this study will become an integral part of the Energy Model Data Base (EMDB) maintained by ERDA. The study is complete only in that it addresses all energy supply and conversion activities. However, a need remains to address the toxic

trace pollutants generated in the energy end use and industrial process sectors of the economy. The data contained in this report are being placed in a computerized retrieval system at Brookhaven National Laboratories (BNL). The BNL computer presently allows for rapid analysis of the environmental residuals produced by various energy systems.

. Austin, Texas. A Western Regional Energy Development Study: Primary Environmental Impacts. Volume I. Final Report. (Radian Corp., Austin, Texas. (USA)). 1 Aug 1975.

Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming contain coal, oil, natural gas, oil shale, tight gas sands, tar sands, uranium, and geothermal resources. The report examines the primary environmental impacts of 38 energy resource development scenarios: the air and water emissions, solid waste, and land requirements of a plant or process. Projected ground level ambient concentrations of pollutants are compared with federal and state standards. Scenarios include all aspects of extraction, conversion, and transportation to the point of end use.

. Austin, Texas. A Western Regional Energy Development Study: Primary Environmental Impacts. Volume II. Final Report. (Radian Corp., Austin, Texas (USA)). 1 Aug 1975.

The report examines the primary environmental impacts of 38 energy resource development scenarios: the air and water emissions, solid waste, and land requirements of a plant of process. Projected ground level ambient concentrations of pollutants are compared with federal and state standards. Scenarios include all aspects of development: extraction, conversion, and transportation to the point of end use.

Banks, C.E., R.I. Benner, L.L. Brannick, and B.C. Franciscotti.
Technical and Economic Study of an Integrated Single Pass Mining System for Open Pit Mining of Deep Oil Shale Deposits. Phase I Report. (Sun Oil Co., Richardson, Tex (USA)). 30 Apr 1975. p. 262.

Data were collected on the geology and hydrology of the Green River Formation in the Piceance Creek Basin, Colorado, on mining reclamation methods and costs, and on surface mining and crushing methods and costs. Data were organized into tables, graphs, and flow charts for engineering analysis. Data from eight large surface mines and a preliminary mine layout for a pit producing 1.25 million tons per day are included.

Burke, H.D. Wildlife and Oil Shale: A Problem Analysis and Research Program. Volume I. Report. Report for 21 Apr-31 Dec 1975. (Thorne Ecological Inst., Boulder, Colorado (USA)). Sep 1975.

The program analysis and research program considers the natural and social environment of the Oil Shale Region of northwestern Colorado, northeastern Utah, and southwestern Wyoming. The purpose was to examine and evaluate the probable consequences of a developing oil shale industry upon the environment, to devise research studies that would evaluate environmental and social changes, and to assist in avoiding or mitigating undesirable changes, particularly as they pertain to wildlife. The analysis was done by a group of nineteen highly qualified scientists with extensive experience in the region or related areas. These scientists reviewed problems and designed appropriate studies. Through screening by sets of 'key questions', the original 162 studies submitted were reduced to 128. Ten studies were selected from this number as 'Priority Studies' recommended for immediate implementation.

Burke, H.D. Wildlife and Oil Shale: A Problem Analysis and Research Program. Volume II. Appendix. Report for 21 Apr-31 Dec 1975. (Thorne Ecological Inst., Boulder, Colorado (USA)). Sep 1975.

The appendix is designed to apply to the program of studies recommended in the problem analysis and research program Volume I. It has two purposes: (1) to provide references that may be used in the preparation of requests for proposals or for studies, and (2) to suggest a core group of references for a reference library for research. The references that follow are listed taxonomically as follows: aquatic ecosystems, water quality, terrestrial ecosystems, industrial impacts on wildlife, reptiles and amphibians, blood-sucking arthropods and disease vectors.

Cannon, W.C. and D.W. Phelps. Generation and Characterization of Oil Shale and Spent Shale Aerosols for Animal Inhalation. Feb 1978.

The purpose of this study is to investigate the potential health hazards associated with exposure to dusts and other effluents released during the processing of oil shale. Potential exists for occupational exposure to oil shale and spent shale particulates, crude shale oil, processed shale oil, and waste water. Polycyclic aromatic hydrocarbons (PAH), including carcinogens, are present in all of the above pollutants. The Wright Dust Feed Mechanism was evaluated as a generator of oil shale and spent shale aerosols for animal inhalation experiments. Oil shale concentrations of 197 mg/m³ were obtained, of which 68% was respirable; spent shale concentrations of 86 mg/m³ were obtained (79% respirable). Both oil shale and spent shale aerosols had particle size-dependent compositions.

Chappell, W.R. (Science Applications, Inc. LaJolla, CA); Toxic Trace Elements and Oil Shale Production. Runnells, D.D. pp 383-388 of Trace substances in environmental health. D.D. Hemphill (ed.). Columbia, MO (7 Jun 1977).

An interdisciplinary, multi-university research team sponsored by ERDA is investigating the potential for release of harmful amounts of trace elements into the environment by the extraction and processing of oil shale. Scientists from the University of Colorado, Colorado State University and the Colorado School of Mines are studying the background levels of trace elements in natural materials, the mass flow through oil shale retorts, the uptake of trace elements by plants and the leachability of trace elements in retorted shales and disturbed soils. This paper briefly describes the program and discusses some of the results obtained to date.

Crawford, K.W., C.H. Prien, L.B. Baboolal, C.C. Shih, and A.A. Lee. A Preliminary Assessment of the Environmental Impacts from Oil Shale Developments. Report for Jul 75-Jul 76. (TRW Environmental Engineering Div., Redondo Beach, Calif. (USA)). Jul 1977.

The report is a summary of major oil shale extraction and retorting development activities. The potential impacts on the physical environment which could result from commercial oil shale development are discussed relative to sources, properties, and quantities of wastes. The report describes existing air, water, and land resources in northwestern Colorado and northeastern Utah. The identification of potential impacts of oil shale development on these resources, pollution control technologies and management plans are reviewed. Potential hazards associated with refining and end use of shale oil products are evaluated. The major environmental monitoring and impact studies are identified, and the scope of oil shale development projects is assessed.

de Nevers, N.D. Eckoff, S. Swanson, B. Glenne and F. Wagner. Analysis of the Environmental Control Technology for Oil Shale Development. (Utah Univ., Salt Lake City, (USA). Coll. of Engineering). Feb 1978.

The environmental control technology proposed in the various oil shale projects which are under development are examined. The technologies for control of air pollution, water pollution, and for the disposal, stabilization, and vegetation of the processed shale were thoroughly investigated. Although some difficulties may be encountered in any of these undertakings, it seems clear that the air and water pollution problems can be solved to meet any applicable standard. There are no published national standards against which to judge the stabilization and vegetation of the processed shale. However, based on the goal of producing an environmentally and aesthetically acceptable finished processed shale pile, it seems probable that this can be accomplished. It is concluded that the environmental control technology is available to meet all current legal requirements. This was not the case before Colorado

changed their applicable Air Pollution regulations in August of 1977; the previous ones for the oil shale region were sufficiently stringent to have caused a problem for the current stage of oil shale development. Similarly, the federal air-quality, non-deterioration regulations could be interpreted in the future in ways which would be difficult for the oil shale industry to comply with. The Utah water-quality, non-deterioration regulations could also be a problem. Thus, the only specific regulations which may be a problem are the non-deterioration parts of air and water quality regulations. The unresolved areas of environmental concern with oil shale processing are mostly for the problems not covered by existing environmental law, e.g., trace metals, polynuclear organics, ground water-quality changes, etc. These may be problems, but no evidence is yet available that these problems will prevent the successful commercialization of oil shale production.

Dorrler, J.S. Energy Resource Extraction; Oil and Gas Production. (U.S. Environmental Protection Agency, Edison, NJ). 1976.

The paper discusses the wastes produced in the extraction, conversion, and utilization of oil and gas, and the pollution control measures used. The overall program includes: developing technology to prevent environmental damage during installation and operation of wells, platforms, and transfer facilities; developing criteria to be used in evaluating sites for onshore pipelines and onshore facilities to support offshore oil and gas production operations; and developing technology to prevent, control, and clean up oil spills.

Epler, J.L., F.W. Larimer, T.K. Rao, C.E. Nix and T. Ho. Energy-related Pollutants in the Environment: The Use of Short-term Tests for Mutagenicity in the Isolation and Identification of Biohazards. (Oak Ridge National Lab., Tenn. (USA)). 1978.

In an effort to gather information on the potential genetic hazards of existing or proposed energy generating or conversion systems, we have begun a correlated analytical and genetic analysis of a number of technologies. The work is divided into two phases: one dealing with known compounds expected to occur in the environment through energy production, conversion, or use; the other dealing with actual samples from existing or experimental processes. To approach the problems of dealing with and the testing of large numbers of compounds, we set up a form of the tier system. Operating units utilizing Salmonella, E. coli, yeast, human leukocytes, mammalian cells, and Drosophila have been initiated. Various liquid-liquid extraction methods and column chromatographic separations have been applied to crude products and effluents from oil shale, coal liquefaction, and coal gasification processes. Mutagenicity of the various fractions is assayed using reversion of histidine-requiring auxotrophs of Salmonella typhimurium and comparative studies are carried out with the other genetic systems. In order to incorporate metabolic activation of these fractions and compounds, rat liver homogenates are used in the various assays. Results implicate chemicals occurring in the basic and the neutral fractions as potential genetic hazards. Chemical constituents of these fractions (identified or predicted) were tested individually for their mutagenic activity and correlated with the genetic monitoring.

Flug, M, W.R. Walker, G.V. Skogerboe, and S.W. Smith. Impact of Energy Development on Water Resources in the Upper Colorado River Basin. Completion Report. (Colorado State Univ., Fort Collins (USA). Dept. of Agricultural Engineering). Aug 1977.

The Upper Colorado River Basin contains appreciable amounts of undeveloped coal, oil shale, and uranium resources, which are important in the national energy demand system. A mathematical model, which simulates the salt and water exchange phase of potential fuel conversions, has been developed, based on a subbasin analysis identifying available mineral and water resources. Potential energy developments are evaluated with respect to the resulting impacts upon both the quantity and salinity of the waters in the Colorado River. Model solutions are generated by use of a multilevel minimum cost linear programming algorithm, minimum cost referring to the cost of developing predetermined levels of energy output. Level one in the model analysis represents an aggregation of subbasins along state boundaries and thereby optimizes energy developments over the five states of the Upper Colorado River Basin. In each of the five second level problems, energy developments over a subbasin division within the respective states are optimized. Development policies which use high salinity waters of the Upper Colorado River enable a net salinity reduction to be realized in the Colorado River at Lee Ferry, Arizona.

Gandolfi, A.J. and C.A. Shields. Absorption of Benzo-a-pyrene From Intratracheally Administered Spent Shale. May 1977.

Tritiated benzo-a-pyrene was adsorbed onto spent shale particles at realistic processing levels. The rate of elution of this ^3H -benzo-a-pyrene from the spent shale was determined in vivo and in vitro.

Gandolfi, A.J. and C.A. Shields. Effect of Intratracheally Administered Oil Shale and Spent Shale on Pulmonary Biotransformation Enzyme Activity.

Rats were dosed intratracheally with suspensions of oil shale, spent shale, or methylcholanthrene/iron oxide. The activities of some important biotransformation enzymes in the lungs and liver were measured to determine any enzyme inductions. None were found.

Guerrieri, S.A. Achieving Energy Self-sufficiency with Coal. (Delaware Univ., Newark (USA)). Arch. Energiewirtsch.; 31: No. 11, 920-933 (Nov 1977).

The report deals with an alternative to the ERDA plan for the utilization and conversion of coal. Combinations of solid, liquid and gaseous fuels are investigated which pursue the target of the ERDA, while meeting the US demand with minimum energy expenditure for the production and consumption of these fuels. The following issues are dealt with a) effects of the changing over of electricity production from oil and natural gas to coal on the one hand,

and from coal coks with simultaneous yielding of coal gas and synthetic crude oil as side-product on the other hand, and b) effects of coal giving for electricity production with separate conversion of coal to synthetic natural gas and synthetic crude oil. A total comparison is made of the alternative methods investigated. The report concludes with recommendations on the coal policy and that of oil shale.

Haywood, F.F., W.D. Cottrell, and H.M. Hubbard, Jr. Radiation Measurements and Assessments. Oct. 1976.

Methods are discussed that were developed to evaluate the characteristics of radiation fields in areas where selected segments in the nuclear fuel cycle or other energy producing operations were carried out resulting in the possibility for exposure to the public. Inactive uranium mills were surveyed for radionuclides in tailings piles that might pose radiation hazards for human populations. The radiation doses from external exposure or from the inhalation or ingestion of ^{222}Rn , ^{230}Th , and ^{226}Ra , and ^{226}Ra daughters in the mill tailings were estimated. Radiation monitoring surveys were also made at number of decommissioned ERDA sites. Gamma sources in soil and associated dose rates in surface air were measured at selected ORNL sites. Solid waste residues from oil shales were monitored for ^{226}Rn content to determine if any health hazards would result from the use of spent shales as fill material or in concrete products. Progress is reported for a study of ways to reduce the radiation exposure of personnel at light water reactors. It was concluded that the occupational exposure at operating LWR sites can be reduced by 10 to 20 percent.

Hendricks, D.W. and J.C. Ward. pp. 215-234 of In Oil Shale. Yen, T.F.; and G.V. Chilingarian. (eds.). Environmental Analysis of an Oil-Shale Industry in the Upper Colorado Region. New York; Elsevier Scientific Publishing Co. (1976).

The analysis includes information on industry development, regional characteristics, changes due to oil shale development, and interactions of regional subsystems.

Hinman, G., and E. Leonard. Air Quality and Energy Development in the Rocky Mountain West. Sep 1977.

Current ambient air quality standards in the six Rocky Mountain states have been used to evaluate limits on the number of energy conversion facilities that can be constructed in nine resource areas in these states. Facilities considered were coal-fired power plants, coal gasification plants, and shale oil extraction facilities. The number of facilities determined in this way is compared to the numbers required in 1980, 2000, and 2020 according to a regionally disaggregated national scenario. The comparison shows that present air quality standards probably will not limit coal development in the Rocky Mountains severely but that extensive oil shale development will not be possible using current facility design. Pollutant dispersion calculations have also been used to approximate the air pollution impacts of full energy development on

health, property, and aesthetics in the region. The impacts will be substantial but not large compared to the cost of control equipment or the regional economic benefits generated by the energy industries. The study brought out the high value of further research and development on reducing emissions from shale oil processing facilities, on better understanding of public perception of changes in visibility, and on knowledge about pollutant transport in mountainous terrain.

Hinman, G.W., and E.M. Leonard. Effects of Energy Development on Air Quality in the Rocky Mountain West. (Los Alamos Scientific Lab., N. Mex. (USA)). 1977

Future need for fossil fuels may lead to an exploitation of Western coal and oil shale at the expense of the traditional clean air and clear skies of the West. This report evaluates the prospects for future changes in western air quality, the constraints imposed on western energy development by air quality regulations and the impacts of that development.

Holland, L.M., M.I. Tillery, D.M. Smith, J.R. Prine, and R.G. Thomas. Oil Shale Toxicity. Jul 1977.

Progress is reported on the following studies on oil shale toxicity: effects of inhalation of raw and retorted shale by hamsters on lungs and hematological values; effects of intratracheal exposure of hamsters on macrophage response and pulmonary epithelium; and histochemical evaluation of lung tissue.

Hoskings, W.N., F.D. Wright, R.L. Tobie, J.B. Bills, R.P. Upadhyay, and C.B. Sandberg. Technical and Economic Study of Candidate Underground Mining Systems for Deep, Thick Oil Shale Deposits. Phase I Report. (Cameron Engineers, Inc., Denver, Colo. (USA)). Jul 1975. p. 319.

Preliminary studies are reported on large-scale mining systems adaptable to the thicker oil shale deposits in the deeper central portion of the Piceance Creek Basin. The studies include an evaluation of the geology, hydrology, and resources of the Basin, evaluation of a potential prototype mine site, synthesis of rock mechanics data on Green River Formation oil shale, selection and preliminary design and cost evaluation of six potential mining systems and ranking analysis to aid in selecting the most promising system. The relative merits of each mining method were defined and the following candidates were selected as most promising for detailed design and analysis under Phase II of the contract; (1) chamber and pillar mining with spent shale backfill; (2) sublevel stopping with spent shale backfill; (3) sublevel stopping with full subsidence; and (4) block caving mining using LDHs (load, haul, dump equipment). Health and safety and environmental aspects are also considered.

Hutchins, J. Status of Oil Shale Conversion Process Technology and Residuals Management. (Oil Shale Consultant, Denver). 1976.

The oil shale deposits in the West and some of the retorting processes and retorts are described. Of the surface retorting processes, only TOSCO II is ready for commercialization. In-situ processes and gasification are also mentioned. The waste and salable products are discussed. It is felt that most of the money spent in environmental studies are just wasted, and a personal view of priorities is offered.

Jones, D.C., W.S. Clarke, W.F. Holland, J.C. Lacy, and E.D. Sethness. Monitoring Environmental Impacts of the Coal and Oil Shale Industries: Research and Development Needs. Final Report. (Radian Corp., Austin, Tex. (USA)). Feb 1977.

Recommendations are presented for monitoring and predictive technology for the coal conversion and oil shale industries. The recommendations are based upon a literature survey of the emissions and potential impacts of these industries. Descriptions of the technologies are included.

Klein, N.W. Embryo Culture in Teratological Surveillance and Serum Proteins in Development. Progress Report, 1977-1978. (Connecticut Univ., Storrs (USA). Dept. of Animal Genetics). Jul 1978.

Studies were conducted on two established teratogens, cadmium and cyclophosphamide, and four substances related to energy technology, coal solid, spent shale particulates, shale oil, and coal oil. Rat embryos were cultured on serum from animals injected with teratogens. Studies were also conducted on regulation of serum protein synthesis using endoderm cell cultures from chick embryos and cell-free synthesis of serum proteins.

Lund, J.E., K.E. McDonald, and L.G. Smith. Late Effects of Oil Shale Pollution. May 1977.

Studies on late effects of oil shale pollutants were initiated during FY 76. Tables list the protocols for investigation of carcinogenic and fibrogenic potential of oil shale particulates. Animals in the long-term study (carcinogenesis) have one remaining intratracheal instillation of particulates to be given and will be observed for an additional 14 months.

Magee, E.M. Evaluation of Pollution Control in Fossil Fuel Conversion Processes. Final Report, Jun 1972-Jan 1976. (Exxon Research and Engineering Co., Linden, N.J. (USA)). Apr 1976.

The review gives an overview of work, between June 1972 and January 1976, on various environmental aspects of fossil fuels. Details of this work is presented in 14 reports published during this same period. The details include potential pollutants in fossil fuels;

quantities of solid, liquid, and gaseous effluents from coal treatment and conversion to gaseous and liquid fuels; and an analytical test plan for coal conversion systems. The overview report discusses commonality and differences in the reviewed processes with emphasis on factors which might affect the environment when the processes are in commercial use. Due to the lack of a sufficient data base, data and research and development needs are also addressed.

McKee, J.M., and S.K. Kunchal. Energy and Water Requirements for an Oil Shale Plant Based on Paraho processes. (Paraho Oil Shale Demonstration, Inc., Grand Junction, Co). Q. Colo. Sch. Mines; 71: No. 4, 49-64(Oct 1976).

A study was performed to identify the net energy and water balance of an oil shale plant, based on actual, demonstrated retorting test conditions of the Paraho process at the Anvil Points facility. The boundary assumed for the study begins with shale in the ground, used to produce synthetic crude and by-products, such as sulfur and ammonia. Energy and water requirements for a 100,000 barrel/day oil shale plant based on direct and indirect mode processes are considered. It is concluded that the water consumption of a shale industry would be modest when compared with that of other energy related industries.

Munson, D.E., and E.G. Young. Dynamic Modeling of Rock Springs Oil Shale Using a Homogeneous Equivalent Maxwell Model. (Sandia Labs., Albuquerque, NM). Int. J. Rock Mech. Min. Sci.; 14: No. 5/6, 283-287(Nov 1977).

Stress pulses propagating through specimens of Rock Springs oil shale show distinct characteristics of rate effects and dispersion. This observation strongly suggests that oil shale is responding as a mechanical mixture, which it is, of kerogen and rock. The dynamic response of such a mixture can be described using a simple Maxwell model in which all input parameters, save one, are deduced from the Hugoniot of the constituents and their volume fractions. An additional parameter, the relaxation time, is selected to give the best agreement with experimental data. Calculations using this model, with a relaxation time of 0.4 ms, produced wave profiles in very good agreement with the measured results; calculated arrival times were within 7.4% and peak particle velocities were within 8.0% of those measured.

Powderly, J.D., and R. Franklin. Oil Shale-FY 1977. (Energy Research and Development Administration, Washington, D.C. (USA)). Jun 1977. p. 56.

This Oil Shale Environmental Development Plan (EDP) identifies and examines the environmental, health, safety, and socio-economic issues concerning the development of the ERDA Oil Shale Program, the requirements and actions needed to resolve these issues, and a time-phased action plan for the evaluation and mitigation of environmental impacts. The Plan addresses the oil shale energy system

including mining, crushing and sizing, fracturing, in situ and surface retorting, product recovery and upgrading, transportation, and end use. The ERDA environmental activities and projects related to the oil shale technology development program are included in this Plan. Also included is a survey of activities of other Federal agencies which relate to oil shale environmental issues and requirements.

Powers, T.J. Environmental Control for Oil Shale Processing. (Environmental Protection Agency, Cincinnati). 1976.

The need for adequate control technologies for the mining and processing of oil shale is explained and EPA's programs toward process control and treatment technology are briefly discussed.

Price, B.J., V.H. Kollman, and G.C. Salzman. Biological Applications of the Multiangle Light-scattering Flow System. Jul 1977.

Progress is reported on the following studies: classification of microalgal species; identification of human abnormal erythrocyte morphologies; a high-efficiency flow cytometer; and evaluation of the dose-effect relationship for the immune response to biologically active agents associated with oil shale technology.

Rajaram, V., T.A. Kauppila, and R.L. Bolmer. Oil Shale Mining and the Environment. (Cleveland-Cliffs Iron Co.). Min. Eng. (N.Y.); 30: No. 4, 360-363 (Apr 1978).

The U.S. Bureau of Mines, which pioneered demonstration mining of oil shale in 1944, commissioned in 1976 the design of a mining research facility in deep, thick oil shale deposits in Colorado. Actual development of the mining research facility is no longer included in the current Bureau of Mines research program. However, such a mine might be developed in the future by government or industry. Chamber and pillar mining with backfill, sublevel stoping with backfill, sublevel stoping with full subsidence, and block caving using LHD's (Loadhaul-dumps) are four mining concepts that were envisioned for demonstration in such a conceptual mine. This paper describes the design of these four mining concepts and the interrelationship of these concepts and the environment.

Schulte, H.F., A.K. Stoker, E.E. Campbell, E.C. Anderson, and G.E. Dials. BER Balanced Program Plan: Oil Shale Technology. (Los Alamos Scientific Lab., N.Mex. (USA)). Jun 1976.

Oil shale technology has been divided into two subtechnologies: surface processing and in situ processing. Definition of the research programs is essentially an amplification of the five King-Muir categories: a) pollutants: characterization, measurement, and monitoring; b) physical and chemical processes and effects; c) health effects; d) ecological processes and effects; and e) integrated assessment. Twenty-three biomedical and environmental research projects are described as to program title, scope, milestones, technology time frame, program unit priority, and estimated program unit cost.

Sims, P.L. Rehabilitation Potential and Practices of Colorado Oil Shale Lands. Progress Report, June 1, 1976-May 31, 1977. (Colorado State Univ., Fort Collins (USA)). Feb 1977.

Substantial progress has been made towards implementing all of the prescribed studies and satisfying the stated objectives since the Oil Shale Rehabilitation Project was actively initiated in June 1976. Concurrent with implementation, research objectives were substantively defined and supplemented without distracting or departing from the original purpose. Current studies are designed to fill voids in the present status of knowledge regarding lands disturbed by an impending oil shale industry in Colorado. The efforts of all contributing investigators have therefore been integrated and directed toward the goal of developing methodologies requisite for restoring diverse and complex ecosystems which will require only a minimal amount of maintenance or input of scarce resources. An intensive study site southeast of the Oil Shale Tract C-a has been obtained through a Cooperative Agreement with the Bureau of Land Management. Following this agreement, most subprojects were initiated at the intensive site. Additional programs will be implemented as spent shale becomes available this summer. Studies conducted principally in the laboratory and greenhouse, such as the microbiological and plant genetic studies, have achieved significant results.

Smith, D.M., G.A. Drake, J.E. London, and R.G. Thomas. Preliminary Toxicological Study of Sylgard 184 Encapsulating Resin: Curing Agent. (Los Alamos Scientific Lab., NM (USA)). Jun 1978.

The acute oral LD₅₀³⁰ values for Sylgard 184 (100 parts encapsulating resins plus 10 parts curing agent) were greater than 5 g/kg in rats and mice. According to classical guidelines, the mixture would be considered slightly toxic or practically nontoxic in both species. Skin application studies in the rabbit demonstrated the mixture to be mildly irritating. Eye irritation tests, also in the rabbit, showed the Sylgard 184 mixture to be a mild but transitory irritant. The sensitization study in the guinea pig demonstrated the mixture to be a very mild sensitizer in two of six animals.

Smith, D.M. Selection of a Model System to Determine the Effects of Energy Production by-products on the Immune system. Progress report, January 1-September 30, 1976. (Los Alamos Scientific Lab., N.Mex. (USA)). Dec 1976.

Immune system function for rats and hamsters is described, and normal values are given for T-cell ³H-uridine uptake, phytohemagglutinin and concanavalin A-induced lymphocyte mutagenesis in vitro with and without 2-mercaptoethanol addition to the cultures, histologic evaluation of phytohemagglutinin skin testing, T-lymphocyte-dependent cytotoxicity. B-lymphocyte erythrocyte-antibody-complement formation and B-lymphocyte globulin production mediated hemolytic plaque production. Also included are erythrocyte-antibody-complement rosette values for blood lymphocytes from thymectomized

hamsters. A pilot study is described in which Syrian hamsters were exposed to aerosolized spent oil shale (33 mg/l respirable mass) 4.5 h a day, 4 days a wk, for 6 wk. Total white blood cell counts, differential white blood cell counts, red blood cell counts, hematocrits, and hemoglobin determinations in experimental animals did not differ significantly from those of control animals.

Steinkamp, J.A., K.M Hansen, J.S. Wilson, G.C. Sanders, D.J. Orbeky, and H.A. Crossman. Detection of Early Changes in Lung Cell Cytology by Flow-systems Analysis Techniques. Progress report. July 1-December 31, 1977. (Los Alamos Scientific Lab., N.Mex. (USA)). Apr 1978.

This report summarizes on-going experiments to develop the logical and biochemical indicators for measuring damage to respiratory tract cells exposed by inhalation of environmental toxic agents. The specific goal of this project is to apply flow cytometric methods to analyze and detect changes in lung epithelium as a function of exposure to toxic agents such as those associated with the production of synthetic fuels from oil shale and coal. The objectives during the past 6 months were to complete modifications to the multiparameter cell separator by adding a krypton laser with an output capability of specific wavelengths ranging from the uv to the ir; analyze and separate lung cells based on their DNA content; evaluate some new fluorescent DNA and protein stains; and treat hamster lung cells with proteolytic enzymes for increasing cell yield. Future experiments will involve the continued analysis and characterization of exfoliated lung cells based primarily on cellular DNA content, protein, morphological features, and specific enzyme activities; quantitation of macrophage activity; exposure of hamsters to toxic agents such as oil shale particulates and ozone; and continued analysis of cells based on DNA content. As this new technology becomes adapted to analyzing respiratory tract cells, the measurement of physical and biochemical cells properties as a function of exposure to toxic agents will be increased. This analytical approach is designed to assist in the establishment of guidelines for estimating risks to exposed humans.

Stone, R.T. Environmental Impact of a Shale Oil Industry. pp 49-51 of In Proceedings of the synthetic hydrocarbons conference. New York; American Inst. of Mining, Metallurgical, and Petroleum Engineers, Inc. (1974).

Potential impacts of the development of an oil shale industry on the land, water, and air are reviewed. It is pointed out that an assessment of water quality and supply is difficult. The role of the oil shale advisory panel and the prototype leasing program, both established by the Interior Department, are discussed.

Utter, S. Developing an Experimental Oil Shale Mine. (Bureau of Mines, Denver). pp. 471-474 of In Proceedings of the third annual UMR-MEC conference on energy crisis, an evaluation of our resource potential. Morgan, J.D. (ed.). North Hollywood, CA; Western Periodicals Co. (1977).

As part of their energy research and development program, the Bureau of Mines is developing an experimental oil shale mine facility in the central Piceance Creek Basin of northwestern Colorado. This paper describes the results of their exploration program and hydrological investigation, the preliminary mine layout, and plans for the large-diameter bored shaft.

Wen, C.S. (Univ. of Southern California, Los Angeles); T.F. Yen, J.B. Knight, and R.E. Poulson. Studies of Soluble Organics in Simulated In Situ Oil-Shale Retort Water by Electron Impact and Chemical Ionization from a Combined Gas Chromatograph-Mass Spectrometer System. Am. Chem. Soc., Div. Fuel Chem., Prepr.; 21: No. 6, 290-291 (1976).

Retort water samples collected from the Laramie 10-ton simulated in situ retort were examined by both electron impact (EI) and chemical ionization (CI) mass spectrometry with a Finnigan Model 3300 gas chromatograph-mass spectrometer (GC-MS). These water samples, formed in retorting Green River oil shale of either Utah or Colorado origin, were filtered, lyophilized, extracted with benzene, and esterified. Both the benzene concentrates, as well as the corresponding methylated fraction were studied. Specific compounds were identified by comparison of EI to known spectra and followed by CI with methane as reagent gas. In general, classes of compounds included n-paraffins, fatty acids, phenolics, substituted benzenes, and nitrogen bases. The presence of acids such as stearic, palmitic, myristic, and lauric may be indicative of the algal components in shales which are precursors of kerogen. On the other hand, compounds such as substituted xylenes and phenols may be formed from thermal decomposition in retorting.

Wilder, M.E., and L.S. Cram. Evaluation of the Dose-effect Relationships for the Immune Response to Biologically Active Agents Associated with Oil Shale and Coal Gasification Technologies, January 1-June 30, 1976. (Los Alamos Scientific Lab., N.Mex. (USA)). Sep 1976.

It is necessary to evaluate the effect of oil shale and coal gasification byproducts on the immune system. The objective of this project is the application of automated flow-systems technology to evaluate the effects of these physical and chemical agents. The program utilizes multiparameter flow-systems cell-analysis and cell-sorting instrumentation developed at the Los Alamos Scientific Laboratory, thus permitting early and accurate assessment of cellular damage to the immune system.

Wildung, R.E., R.G. Riley, T.R. Garland, R.M. Bean, and S.W. Li.
Terrestrial Effects of Oil Shale Development. May 1977.

Research programs to assess the terrestrial effects of oil shale mining and extraction were initiated. Preliminary data as reported on the development of appropriate analytical techniques to determine the mobility of organics in spent shales and soils, microbial alteration of these compounds, and their plant availability.

Wiley, W.R. Pacific Northwest Laboratory Annual Report for 1977 to the DOE Assistant Secretary for Environment. Part 1. Biomedical Sciences. (Battelle Pacific Northwest Labs., Richland, Wash, (USA)). Feb 1978.

Separate abstracts were prepared for 68 sections of this report that discuss the health hazards associated with the nuclear fuel cycle, fossil fuel cycle, oil shale processing, and biomagnetic effects associated with fusion. A list is included of 52 publications during the time period covered by this report.

Environmental Research Program, 1976.

In Energy and Environment Division annual report, 1976.

The scope of the Environmental Research Program can be divided into three broad categories of projects on energy related environmental issues. The first category is composed of investigations of problems relating to the effects of trace metals and methyl mercury in marine and fresh water systems. The next category includes atmospheric aerosol studies and investigations on indoor and outdoor air pollution by particulates and gaseous pollutants from fossil fuel combustion. The health and safety impacts project has been performed in order to establish a methodology for the review of the health and safety aspects of proposed nuclear, geothermal, and fossil fuel electric generation sites and facilities in California. The cell membrane project is involved in studying the role of membranes in damage and protection of cells against environmental effects, including the determination of how and where various pollutants act on membrane structures. The study of water conservation with in situ oil shale development has objectives of identifying and assessing water related impacts of in situ oil shale development and developing control measures to mitigate adverse impacts. Finally, a study is being performed on the environmental impacts of the Geysers geothermal development and the proposed development at immediately adjacent Lake County.

Environmental Impacts - Air Pollution

. Washington, D.C. Advanced Fossil Fuel and the Environment: an Executive Report. (Environmental Protection Agency, Washington, D.C. (USA)). Jun 1977. p. 27.

The environmental control technologies being developed in conjunction with advanced fossil fuel conversion processes are briefly reviewed. These programs include chemical coal cleaning, synthetic fuels, chemically active fluid bed, oil shale, and liquid fuels cleaning. Comparative economics of sulfur control and a reading list are included.

Cavanaugh, E.C., G.M. Clancy, J.D. Colley, P.S. Dzierlenga, and V.M. Felix. Atmospheric Pollution Potential from Fossil-fuel Resource Extraction, On-site Processing, and Transportation. Final Report. Jan-Dec 1975. (Radian Corp., Austin, Tex. (USA)). Mar 1976.

The report describes the processes and operations employed for the production, on-site processing, and transportation of coal, oil, oil shale, and gas. Typical processing sequences are represented by modules. For each module, identification and quantification of potential atmospheric emissions is achieved through the use of existing information. A review of emission source monitoring methods, as well as a study of possible source control methods, is presented.

Environmental Impacts - Socio-economics

Christiansen, B. (Lieutenant Governor of the State of Montana); and T.H. Clack, Jr. Western Perspective on Energy: A Plea for Rational Energy Planning. Science: 194: No. 4265, 578-584 (5 Nov 1976).

The immense reserves of the Rocky Mountain region are perceived to be the short- and mid-term answer to the energy crisis. The Federal government and the energy industry have prepared plans to develop western energy resources; these reserves would be of far greater value as future sources of hydrocarbons than as simple fuels for the present. Two major Federal plans show that the public is not aware, nor has it been informed, that severe energy, food, and materials shortages are imminent. The first proposal outlines the administration's plan to achieve the objectives of Project Independence. The second document, issued by the Department of the Interior in 1974, outlines the Federal government's plans to expand leasing of Federal coal lands and the reasons for doing so. The impacts not cited or considered in the documents are then reviewed. While admitting it is easier to criticize than to find solutions, the authors discuss five suggestions; the problem should be rationally and comprehensively assessed; specific plans must be developed; alternative energy futures should be considered; a commitment to preserve natural and social values is necessary; and commitment to public access and information is essential. The public and their elected representatives must define the optimum use of the nation's remaining energy reserves before an irrevocable decision is made concerning their fate.

Gilmore, J.S., K.D. Moore, D. Hammond, and D. Coddington. Analysis of Financing Problems in Coal and Oil Shale Boom Towns. Final Report. (Denver Research Inst., Colo. (USA)). Jul 1976.

The report is a case study of impacts resulting from energy development in four communities. For each community the adequacy of facilities, the tax revenues, and capital needs for facility construction are examined. A variety of financing options are evaluated for their effectiveness based on eight criteria.

Schaub, J.R., J.R. Barse, and L.D. Bender. Research Program on the Economic and Social Consequences of Coal and Oil Shale Development. (Economic Research Service, Washington, DC). 1976.

Research is done to gather information on problems affecting supplies of food and fiber and to evaluate the effect of various agricultural and rural policies and programs as they relate to the use of natural resources, agricultural production and productivity, and the social and economic vitality of rural communities.

Water Requirements

Bishop, A.B., M.D. Chambers, W.O. Mace, and D.W. Mills. Water as a Factor in Energy Resources Development. (Utah State Univ., Logan (USA). Utah Water Research Lab.). Jun 1975.

Water is a key input to western energy resource development. Particularly where water supplies are short and water quality degradation is a critical consideration, the water resource system conflicts associated with energy development at alternative sites need to be carefully examined. To demonstrate the model structure and capabilities, an application is made to the energy resource region within the Utah portion of the Colorado River Basin. Surface water resources available by stream reaches are designated, and the possible energy developments requiring water inputs, for both extraction and conversion processes, are located. For the initial application of the model, optimal solutions were obtained for both energy maximization and water minimization which illustrate composite system effects and potential conflicts that could arise from various combinations of water allocation to energy resources developments.

Bishop, F.A. Industrial Water Availability: Western States Opportunities and Problems. pp. 81-83 of In Proceedings of the synthetic hydrocarbons conference. New York; American Inst. of Mining, Metallurgical, and Petroleum Engineers, Inc. (1974).

Wyoming's massive energy resources, coupled with the developing energy crisis, have focused national attention on the state, which ranks second in uranium reserves, fifth in crude oil, seventh in natural gas, and ninth in coal, according to a recent report by the Bureau of Mines. The pressures of the worldwide energy crisis will inevitably lead to rapid expansion in the development and production of these fuels. The additional factor of a low sulphur content in Wyoming coals has attracted attention from those industries capable of using coal as a fuel across the nation. Wyoming's major industrial growth appears to lie in the field of coal and oil-shale development. Generally speaking, the oil-shale reserves are located in the drainage of the Colorado River in the southwestern part of the state, and in an area of water surplus for Wyoming. Although there are many unknowns concerning the water requirements of an oil shale industry, it would appear that adequate water should be available to supply demands in this area of Wyoming. The picture concerning coal development is not nearly so clear. A large part of Wyoming is underlain with coal, but the most attractive coals are concentrated in northeastern Wyoming. This area of the state is short of water, with agricultural development having already committed most of the readily available local water supplies. The availability of water will be a critical factor in determining the extent of coal development in northeastern Wyoming. If adequate water becomes available, there will be significant industrial

development, including coal-fired electrical generating plants and various kinds of synthetic fuel production plants located near the coal deposits. If water is not available, the coal will probably be mined and shipped out of the area. Realistically, the end result will most likely be some combination of these two approaches, with water availability playing a major role in defining the mix.

Decora, A.W. Internal Quarterly Progress Report, April-June 1976.
(Energy Research and Development Administration, Laramie, Wyo.
(USA) Laramie Energy Research Center). Jul 1976.

Coring of the test interval at LERC's Tar Sand Recovery Site was completed. Tar sand intervals above the test zone were also cored in an attempt to locate another suitable zone for the second field experiment. Core analysis indicates that a suitable zone is not present above the first test interval. A well has been drilled south of the first test pattern. Core analysis has been completed, and air-injection tests are being conducted. Kinetic data obtained on five whole tar sands indicate a first order reaction for bitumen pyrolysis. The apparent activation energies for all five samples are similar, suggesting similar reactivities and pyrolysis pathways. Successful ignition and operation of the in situ oil shale experiment at Rock Springs site 9 continued during this quarter. In research supporting the in situ field experiments on oil shale, bench-scale studies and one test in the 10-ton retort were completed as part of a program designed to provide comprehensive data for resolution of temperature anomalies previously observed during retorting tests of large oil shale blocks. Results indicate that the formation of secondary thermocouple junctions give rise to the anomalous and erroneous temperature measurements. Thirty-four retort runs were completed on various phases of gasification of oil shale. Routine water sampling at Site 9 and in the Upper Green River Basin wells was continued. Retort studies at Anvil Points this quarter consisted of completing retorting runs with conditions that would provide required data points for a commercial design. In studies on the underground gasification of coal, the reverse combustion link from Well 6 to 5 was completed with successful results. In addition, the reverse combustion link from the 5-6 line to the 7-8 line was completed.

Gold, H., D.J. Goldstain, R.F. Probst, J.S. Shen, and D. Yung.
Water Requirements for Steam-electric Power Generation and Synthetic Fuel Plants in the Western United States. Final Report May-Aug 76. (Water Purification Associates, Cambridge, Mass. (USA); Oklahoma Univ., Norman (USA). Science and Public Policy Program). Apr 1977.

The report describes the procedures for the detailed determination of the water consumed for mining and processing coal and oil shale, and for determining the residuals generated. The processes considered are Lurgi, Synthane, and Synthoil for coal conversion, TOSCO II for shale conversion, coal-fired steam electric power generation and slurry pipeline. In addition, determinations are also made of

the water consumed for process cooling, flue gas desulfurization, revegetation of mined land, solids disposal and by evaporation and other uses within the mine-plant complex.

Sparks, F.L. Water and the Oil Shale Industry in Colorado. pp. 91-93 of In Proceedings of the synthetic hydrocarbons conference. New York; American Inst. of Mining, Metallurgical, and Petroleum Engineers, Inc. (1974).

Results of four studies on water requirements of an oil shale industry in Colorado are given. These estimates range from 130,000 acre feet/year in 1959 to 175,000 acre feet/year in 1974. It is pointed out that current figures would probably be higher. It is concluded that 250,000 acre feet/year of water could be made available to a mature oil shale industry.

Production Technology

Progress In Oil-shale Research. Feb 1977.

Oil shale today appears to offer the best chance of providing substantial quantities of synthetic fuels at competitive prices. Oil-shale deposits in Colorado, Utah, and Wyoming contain more oil than Middle East petroleum reserves. The Piceance Basin in western Colorado contains the bulk of these oil-shale resources that are economically recoverable, of which 350 billion barrels are thought to be exploitable with LLL's rubble in situ extraction (RISE) method. Like other modified in situ processes, RISE calls for breaking up the shale by mining methods and heating it underground to free the oil. Modified in situ extraction now appears to be the prime contender for commercial exploitation, with an excellent chance for large-scale field testing. Although more research and development are clearly needed, advances have been made toward realizing the RISE concept since the last report. Important theoretical and experimental results to date are summarized.

. Salt Lake City, Utah. BX In Situ Oil Shale Project Quarterly Progress Report No. 1, March 1-May 31, 1977. (Equity Oil., Salt Lake City, Utah (USA)). 10 Jun 1977.

Activities in an in situ oil shale retorting demonstration are reported. The demonstration project is located in Rio Blanco County, Colorado. Owing to the delay in execution of the agreement, the project is modestly behind schedule, but it is felt that it will be possible to complete all the field work related to the Leached Zone Site Evaluation prior to mid July 1977, and consequently it should be possible to be on schedule with the balance of the project. The work accomplished at the project site to date relates totally to the Leached Zone Site Evaluation, and a separate report covering that matter will be submitted upon completion of the Vertical Communication Test.

. Denver, Colorado. Geochemical Survey of the Western Energy Regions (formerly Geochemical Survey of the Western Coal Regions). Third Annual Progress Report, July 1976. (Geological Survey, Denver, Colo. (USA)). 1976.

Data are presented from a broad scale geochemical survey of landscape materials in the major coal, uranium, and oil shale-bearing lands in the western United States. Data are included on the chemical composition of samples of rocks, soils, surface water, and plants collected in Arizona, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, and Wyoming during 1976.

. Livermore, California. In-Place Shale Process:
More Oil, Less Digging. (Univ. of California, Livermore). Ind.
Res.; 17; No. 6, 14-15 (Jun 1975).

Lawrence Livermore Laboratory, in a conceptual investigation being conducted for the U.S. Energy Research and Development Administration (ERDA), estimates that one shale oil resource in western Colorado could produce oil at a cost of \$6 to \$9/bbl. The recovery method would use explosives to shatter the shale underground and ignite the rubble formed to force oil downward to collector pipes for pumping to the surface. Fracturing the shale would allow heat to penetrate the rock despite its insulating properties and facilitate liquefaction and collection of the oil. The process could produce as much as 2 million bbl/day within six years of the start of development of a site.

. Austin, Texas. A Western Regional Energy Develop-
ment Study: Primary Environmental Impacts. Appendices. Final
Report. (Radian Corp., Austin, Tex. (USA)). 1 Aug 1975.

Water availability and air pollution and water pollution regulations are discussed.

Ackerman, F.J., W.A. Sandholtz, J.H. Raley, and B.H. Laswell. (eds.). Oil Shale Project Run Summary for Small Retort Run S-10. (Calif-
ornia Univ., Livermore (USA). Lawrence Livermore Lab). Jun 1978.

A combustion run using sidewall heaters to control heat loss and computer control to set heater power were conducted to study the effectiveness of the heater control system, compare results with a one-dimensional retort model when radial heat loss is not significant, and determine effects of recycling off-gas to the retort (by comparison with future runs). It is concluded that adequate simulation of in situ processing in laboratory retorts requires control of heat losses.

Allred, V.D. Combined Combustion for In Situ Retorting of Oil Shales.
(To Marathon Oil Co.). US. Patent 4,084,640. 18 Apr 1978.

Shale oil is recovered from oil shale formations by rubblizing or otherwise fracturing the formation establishing zones for an oxidizing gas injection and off gas and product recovery, igniting the formation at a point intermediate between the injection and recovery zones, which is the first phase of the process, causing a heat front to move cocurrent and a combustion front countercurrent to the injected gas stream. This is followed by a second process phase which occurs when the combustion front reaches the zone of oxidant injection and reverses itself oxidizing the residual organic matter laid down on the retorted shale and supplying additional heat to continue the heat from movement to the product recovery zone and completing the retorting of the shale downstream from the ignition zone while recovering heat from the retorted shale in the form of gas preheat.

Ash, J.L., R.B. Stone, W.E. Craig, and M.R. Engler. Technical and Economic Study of the Modified In Situ Process for Oil Shale. Volume I. Investigation and Results. Final Report, 1976. (Fenix and Scission, Inc., Tulsa, Okla. (USA)). Nov 1976.

This report contains the results of a technical and economic evaluation of conceptual systems for the underground mining, rubblization, and in situ retorting of deep oil shale deposits. Study efforts were first directed towards evaluation of the applicable geology, associated minerals, rock mechanics, in situ retorting, access mining, ventilation, rubblization, safety, and environmental impact factors. Conceptual systems were synthesized and then evaluated against these factors from both a technical and limited economic viewpoint. The results of these evaluations were then analyzed and, based on this analysis, two systems were selected for further study. Volume I describes the investigation and results.

Bartel, W.J. and R.S. Burton, III. Multi-stage Method of Operating an In situ Oil Shale Retort. (to Occidental Oil Shale, Inc.). US Patent 4,072,350. 7 Feb 1978.

A method of processing oil shale is described in which an in situ oil shale retort comprising an elongated cavity containing a fragmented permeable mass of formation particles containing oil shale is formed in a subterranean formation containing oil shale to recover liquid and gaseous products. Access to the cavity is by a drift or conduit at each end of the cavity and through a drift at an intermediate position. A processing zone is established in the fragmented mass at one end of the cavity and processing gas is introduced at that end of the retort and heating of the fragmented mass of formation particles is conducted from that end towards the other end. Initially, off gas is withdrawn at the intermediate drift. When the processing zone passes the intermediate drift, processing gas is introduced through the intermediate drift and off gas including gaseous products is withdrawn by the way of the drift at the other end. As the processing zone passes the intermediate drift, processing gas is introduced at one end and off gas is withdrawn from the other end of the retort.

Beard, T.N. In-place Recovery of Multiple Products From Colorado's Saline-mineral-bearing Piceance Basin. (Energy Research and Development Administration, Laramie, WY); and J.W. Smith. AICHE Symp. Ser.; 72: No. 155,32-38(1976).

In-place production of oil and associated minerals from oil shale offers several advantages over more conventional processes. The lack of primary porosity or permeability of oil shale is the principal problem facing this in situ production. Leaching nahcolite from Colorado oil-shale sections can create bounded porosity and permeability, which can then be exploited to produce oil, sodium carbonates and alumina.

Belosel'skii, B.S., V.K. Solyakov, I.S. Konstantinov, and V.D. Konakotin. Use of Liquid Heat Carriers to Upgrade Fuels and to Prepare them for Combustion. (Moscow Power Inst.). Therm. Eng. (USSR); (engl. Transl.); 22: No. 12, 25-28(Dec 1976).

In recent years investigations into use of liquid heat carrier, including organic liquids, melts of salts, oxides and metals have been started in the field of fuel processing. Moscow Power Institute carried out theoretical and experimental investigations into the use for processing of solid and liquid fuels (coals, shales, high sulphur content fuel oils), melts of salts, metals and slags from power stations and from metallurgical works. The investigations have shown that, in principle, liquid heat carriers are suitable for processing a great many fuels both for power generation only and for power generation and technological purposes. The region of the most efficient use of liquid heat carriers for different fuels and systems of using them has been determined. In particular, a liquid metal heat carrier (melt of iron, lead, aluminium and other metals) is preferred for processing of high-sulphur oils. Slag melts are most efficient for processing high-ash solid fuels; in this case the excess molten slag may be used in stone-casting production for manufacturing slag-felt, decorative facing plates and other items in great demand in the national economy. The processing of high-ash fuel with use of molten slag as a heat carrier makes it possible to use efficiently not only the organic part but also the mineral part of the fuel.

Bielova, E. Development and Prospects of Molten Salt Reactors. Jad. Energ.; 22: No. 10, 391-394(Nov 1976). (In Czech).

The characteristics and the problems of molten salt reactor concept are described on the basis of experience with the construction of the MSRE experimental reactor and of the MSBR breeder reactor. The molten salt reactors used as thermal converters are described in detail as is their technology. Graphs are listed of the relations between the conversion ratio and thorium concentration, of the time course of the heavy element isotopes in the converter core, and of the fuel cycle costs of the converter. The molten salt reactors as thermal converters have the advantage of using plutonium from other reactors without requiring fuel element production. Reactors of this type also have specific safety features. Special problems are posed by the spreading of fission products into the entire primary coolant circuit, by increased tritium production and by tritium diffusion capacity.

Bloomfield, H.S. In-situ Laser Retorting of Oil Shale. (to National Aeronautics and Space Administration). US Patent 4,061,190. 6 Dec 1977. p. 6.

Oil shale formations are retorted in situ and gaseous hydrocarbon products recovered by drilling two or more wells into an oil shale formation underneath the surface of the ground; fracturing a region

of said oil shale formation by directing a high energy laser beam into one of said wells and focusing said laser beam onto said region of said oil shale formation from a laser optical system; forcing a compressed gas into said well through which said laser beam was directed at the site of said fracture which supports combustion in the flame front ignited by said laser beam in the fracture region of said oil shale, thereby retorting said oil shale; and recovering gaseous hydrocarbon products which permeate through said fractured oil shale from one of said wells through which the laser was not directed.

Boade, R.R. (ed.). Oil Shale Programs Sixth Quarterly Report, April 1977-June 1977. (Sandia Labs., Albuquerque, N.Mex. (USA)). Oct 1977.

The Sandia oil shale effort consists of the following three programs: (1) Diagnostics and Rock Mechanics Support for the Laramie Energy Research Center (LERC) In Situ Oil Shale Program, (2) Advanced Instrumentation and Field Projects for In Situ Oil Shale Processing, and (3) In Situ Oil Shale Bed Preparation Study. Activities associated with each of these three programs are considered individually.

Boade, R.R. (ed.). Oil Shale Programs. Seventh Quarterly Report, July 1977-September 1977. (Sandia Labs., Albuquerque, N.Mex. (USA)). Oct Feb 1978.

In work on diagnostics and rock mechanics all activities of the quarter were directly related to the oil shale rubbleization experiment which is in progress at Site 12 of the LERC field laboratory near Rock Springs, Wyoming. This experiment is being performed to assess the merits of a hydraulic/explosive concept for preparing an underground oil shale bed for in situ processing. The concept under examination involves the formation of three (nearly) equally spaced horizontal hydrofractures in an underground oil shale bed, the insertion of explosive slurry into the lower two hydrofractures from intersecting wellbores, and finally the detonation of the explosive to produce stress waves which, if the concept is viable, will result in considerable dynamic fracturing of the shale. In work on advanced instrumentation, instruments to measure downhole resistivity, temperature and pressure have been installed in two wells. The primary function of these instruments is to detect changes in formation conditions caused by retort burns in nearby wells or by efforts to initiate such burns. Work on in situ oil shale bed preparation included analytical and experimental efforts to improve data acquisition and interpretation procedures, incorporation of previously obtained information regarding the dynamic fracture of oil shale into a computation code, and numerical calculations to examine several variations of the borehole springing method for preparing an oil shale for retorting.

Boade, R.R. (ed.). Oil Shale Programs. Eighth Quarterly Report, October 1977-December 1977. (Sandia Labs., Albuquerque, N.Mex, (USA)). May 1978.

Activities are reported in a program to develop the technology needed for the in situ processing of oil shale, to demonstrate the technical feasibility of such processing, and to evaluate its economic viability. The effort to teach these objectives is made by providing technical assistance and field support to Laramie Energy Research Center (LERC) for specific field projects. The activities of the present reporting period have been confined to the hydraulic/explosive fracturing experiment which is in progress at Site 12 of the LERC field laboratory near Rock Springs, Wyoming. The highlight of the quarter was the successful execution of the explosive portion of this experiment on December 1, 1977. This successful event was particularly significant since a previous attempt to detonate four months earlier (August 10) had failed. Important aspects of the Site 12 experiment are given. In support projects for in situ oil shale processing development of equipment and techniques for use in monitoring, controlling, and evaluating in situ oil shale fracturing and retorting events are reported. In other work, instrumentation and analytical support for oil shale projects which draw financial support from the DOE was provided. In work devoted to in situ shale bed preparation dynamic and quasi-static laboratory experiments are in progress to examine the deformation and fracture behavior of various grades of oil shale and work is underway to develop and verify computational procedures for field applications. The selection of particular tasks for study is based in part on the immediate needs of the other oil shale activities and also on longer term requirements established by the overall goals of the program.

Braun, R.L. and R.C. Chin. Computer Model for In Situ Oil Shale Retorting: Effects of Input-gas Properties. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 30 Mar 1977.

A one-dimensional mathematical model has been developed for simulating the chemico-physical processes involved in the concurrent, vertical retorting of a rubblized bed of oil shale. Both hot-gas retorting and combustion retorting can be simulated. The flow rate of the gas stream and the composition and temperature of both the gas stream and the shale particles are calculated as a function of time and location in the retort. The rates of recovery of oil and water from the retort are also computed. The model is used to predict commercial in situ retorting phenomena for typical conditions of shale composition, particle size, packing fraction, and input-gas properties. The predicted effects of input-gas properties (flow rate, temperature, and composition) are examined in detail. The model indicates that a gas input of air diluted with steam or CO₂ is effective in controlling the temperature and maximizing the oil yield, without causing the large decrease in retorting rate associated with the use of a mixture of air and recycle gas. The air/steam mixture is also attractive because it yields a retort product gas with a higher heating value.

Braun, R.L. and R.C.Y. Chin. Progress Report on Computer Model for In Situ Oil Shale Retorting. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 14 Jul 1977.

A one-dimensional mathematical model has been developed for simulating the chemico-physical processes involved in the concurrent, vertical retorting of a rubblized bed of oil shale. Included in the present model are those processes believed to have the greatest effects in either the hot-gas retorting mode or the combustion retorting mode. The physical processes are: axial convective transport of heat and mass caused by the bulk gas flow, axial conductive transport of heat, heat transfer between the gas stream and the shale particles, and water evaporation and condensation. The chemical reactions in the shale particles are: decomposition of kerogen and carbonate minerals, reaction of carbon with CO_2 and O_2 , thermal degradation of oil, and release of fixed water. The chemical reactions in the gas stream are: combustion of CO produced from the reaction of carbon with CO_2 , combustion of the fuel components in recycle gas, and oil combustion. The governing equations are solved numerically by a semi-implicit, finite-difference method. Gas stream flow rate as well as the composition and temperature of both the gas stream and the shale particles are calculated as a function of time and location in the retort. Recovery rates of oil and water from the retort are also computed.

Burham, A.K. Reaction Kinetics Between CO_2 and Oil Shale Char. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 22 Mar 1978.

The reaction kinetics between CO_2 and char from Colorado oil shale (Mahogany Zone) have been investigated with isothermal and nonisothermal methods. The results are interpreted in terms of the reaction of char with both externally supplied CO_2 and with CO_2 formed from the decomposition of carbonates in the shale. It was found that oil shale char is approximately an order of magnitude more reactive than both subbituminous coal char and acid-leached oil shale char. This seems to indicate a significant catalytic effect by mineral matter in the oil shale char. Oil shale chars produced at fast heating rates ($>1^\circ\text{C}/\text{min}$) tend to be more reactive than those produced at slow heating rates ($2^\circ\text{C}/\text{h}$). This lower reactivity probably is related to oil coking.

Burton, T.S., III., C.Y. Cha, and R.D. Ridley. Apparatus for Obtaining Uniform gas Flow Through an In Situ Oil Shale Retort. (to Occidental Petroleum Corp.). US Patent 3,941,421. 2 Mar 1976.

An in situ oil shale retort is described in which a cavity filled with broken particles of oil shale is formed within the subsurface oil shale formation and air is forced down through the cavity to sustain combustion of the top layer of oil shale particles. The products of combustion are withdrawn through a plurality of transverse exhaust pipes at the bottom of the cavity, the exhaust pipes each being provided with a series of holes along the length of the pipes within the cavity, the holes being graded in size to compensate for the pressure drop along the length of the pipe so as to provide substantially equal volume of gas flow through each of the openings.

Burwell, E.L. and I.A. Jacobson, Jr. Pipeline Gas From Oil Shale. (Laramie Research Center, WY). Q. Colo. Sch. Mines; 71: No. 4, 139-152(Oct 1976).

A report is given on the volume and calorific value of gas produced using various combinations of pressure and CO₂ and O₂ injection, while holding oil shale grade, water injection, and flux constant. Calorific value of produced gases ranged up to 1,300 Btu/ft³. Oil recoveries of up to 70 percent of Fischer assay were observed, concurrent with the production of 476 Btu/ft³ gas. Production of pipeline quality gas at low pressures, concurrent with shale oil production, appears technically feasible.

Campbell, J.H., (Univ. of California, Livermore), G.H. Koskinas, N.D. Stout, and T.T. Coburn. Oil Shale Retorting: Effects of Particle Size and Heating Rate on Oil Evolution and Intraparticle Oil Degradation. In Situ; 2: No. 1, 1-47(1978).

The evolution of oil during pyrolysis of blocks and powders of oil shale has been investigated using heating rates from 2 to 180°C/h. Blocks (in the form of right circular cylinders) ranged from 3.2- to 17-cm dia, and from 14 to 49 gal/ton in grade. The results show that coking reactions are the major source of intraparticle oil degradation. Furthermore, the degree of coking depends strongly on the heating rate but is nearly independent of particle size and grade for the conditions used. For example, at a heating rate of 2°C/h, 83 percent of Fischer Assay oil is collected, whereas at a rate of 180°C/h the yield is 99 percent. These results are the same (to within ± 2 percent) for both powders and 17.2-cm dia blocks. The experimental results from the 17.2-cm blocks are analyzed using a simple mathematical model based on kinetic results from powder retorting experiments and thermal data reported in the literature. The model calculations for the rate of oil production, the degree of oil degradation, and the thermal profile through the material are found to agree very closely with the experimental data. Finally, the practical implications of this work toward field retorting are discussed.

Carley, J.F. and R.L. Braun. Ignition of In Situ Oil-shale Retorts With Hot Inert Gas. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 17 Feb 1978.

For controlled-combustion retorting of oil-shale rubble in situ, preheating with hot, inert gas appears to be a promising method to prepare the rubble for ignition. By thus setting up an initial separation between the combustion and retorting fronts, oil burning should be reduced and temperatures should remain below those at which spent shale fuses. Inert-gas preheating has been investigated by simulation, using the LLL computer model of in situ retorting. The model explored the effects of: temperature and flow rate of preheating gas, depth that ignition-range temperatures penetrated before changeover to retorting, temperature at the given depth of changeover, and staged changeover. Several sets of conditions gave retort temperatures below 1000°C with low fuel usage. The choices of preheating factors strongly affect the maximum temperatures reached shortly after changeover. The cost of inert-gas startup appears to be small.

Carley, J.F. and L. Thigpen. Modeling of Vertical Pressure Distribution in Large In Situ Retorts. (California Univ., Livermore (USA). Lawrence Livermore Lab.). Apr 1977.

Deformation of oil-shale rubble and its consequent permeability loss depends upon rock pressure. This pressure distribution in oil-shale rubble columns is therefore important to modified in situ oil extraction from oil shale. Pressure distribution in unretorted columns of oil-shale rubble has been modeled using the theory of bins. Dependence of vertical pressure on column geometry and shale properties was examined. A major finding is that, at room temperature for a given geometry and properties, pressure approaches an asymptotic limit regardless of overburden forces. The model has been extended to include variations in density and frictional properties of shale that accompany the temperature changes occurring during retorting and this expanded model has been programmed for the CDC 7600 computer. Parametric studies with this program point up the urgent need for data on the dependence of interparticle frictional properties on temperature and pressure. Directions of further development and improvement of this modeling effort are discussed.

Carpenter, H.C., E.L. Burwell, and H.W. Sohns. Engineering Aspects of Processing Oil Shale By In Situ Retorting. pp. 236-254 of In Chemistry of petroleum processing and extraction. II. New York; MSS Information Corporation(1976).

The Bureau of Mines is conducting in situ retorting experiments in Green River oil shale at a site near Rock Springs, Wyo. A hexagonal well pattern was designed, wells were drilled, and an evaluation of natural permeability was made. Fifty-one wells were each filled from a depth of 145 feet to 110 feet with approximately 420 pounds of explosive. The explosive in groups of two to four wells was simultaneously detonated to fracture the oil shale formation. This explosive fracturing induced multiple horizontal fractures that were confined to a zone from 124.5 to 129.0 feet below the surface. The oil shale was ignited with a propane burner, and combustion was continued using organic material in the formation as fuel. Sufficient surface area to sustain combustion at a satisfactory rate was not produced in this experiment by explosive fracturing; consequently, a hydraulic fracturing treatment was used to produce additional fractures. Combustion of shale in the hydraulic fracture system was started but also was limited by the availability of fuel. Only a small quantity of oil was produced during the entire experiment. Sufficient energy was released and left in the formation to retort about 2,000 tons of oil shale; however, from the observed temperatures and the amount of carbonate decompositions it was concluded that the energy was dissipated so widely that much less than 2,000 tons were heated to retorting temperature.

Carpenter, H.C., E.L. Burwell, J.J. Cummins, J.J. Duvall, and R.L. Wise. Preliminary Results of Five Oil Shale Conversion Experiments at Laramie Energy Research Center. (Laramie Research Center, WY). Q. Colo. Sch. Mines; 71: No. 4, 125-138 (Oct 1976).

Preliminary results of five oil shale conversion experiments being conducted at the Laramie Energy Research Center are presented. These include some early results from the Rock Springs, site 9, in situ retorting experiment; concurrent gasification and retorting studies that have produced gas, exiting from the retort varying in heating value from 50 to 1300 Btu/ft³; retorting tests with the controlled state retort using air instead of nitrogen, resulting in some variation in the obtained results; retorting oil shale under pressure which indicated only slight decreases in oil recovery when using a nitrogen atmosphere, while large increases in oil recovery were observed when using hydrogen atmosphere; conversion of kerogen to usable products, using carbon monoxide water reaction, resulting in higher kerogen conversion at lower temperatures.

Carpenter, H.C. In Situ Oil Shale Retorting Technology. (Laramie Research Center, WY). Apr 1976.

Because in situ retorting may be applicable to a large part of the oil shale found in the United States and because it may have economic and environmental advantages over other methods of processing, it has been investigated by government and industry. The extent of the investigations has been somewhat limited, but the modified in situ method which requires some mining shows technical promise. Research areas concerned with breaking the shale to produce permeability and surface area, concerned with measuring the breakage, and concerned with determining retorting parameters and environmental effects require additional effort to develop in situ oil shale retorting technology.

Carpenter, H.C., H.B. Jensen, and A.W. Decora. Potential Shale Oil Production Processes. (Laramie Energy Research Center, WY). Am. Chem. Soc. Div. Fuel Chem., Prepr.; 22: No. 3, 48-65 (1977).

The recovery of energy from oil shale has been investigated for well over a hundred years. Oil shale industries have existed in a number of countries including an infant industry in the eastern United States that was terminated after the discovery of petroleum in Pennsylvania. Research on oil shale processing has not kept pace with the increased demand for liquid hydrocarbons used as fuels and petrochemical feedstocks. With the present day demand for liquid hydrocarbons and the availability of petroleum, increasing interest in oil shale processing is evident. Potential shale oil production in the United States in the immediate future depends on above ground retorts developed by the U.S. Bureau of Mines and by a limited number of private companies shortly after World War II. Recent developments in modified in situ retorting technology may also be an alternative method for shale oil production.

Cha, C.Y. Decreasing Hydrogen Sulfide Concentration of a Gas. (to Occidental Oil Shale, Inc.). US Patent 4,086,962. 2 May 1978.

The hydrogen sulfide concentration and total sulfur concentration of a gas of relatively higher hydrogen sulfide and total sulfur concentration are reduced by combining hydrogen sulfide in the gas with oxygen in the presence of a fragmented permeable mass of particles containing oil shale treated to remove organic materials to yield a gas with relatively lower hydrogen sulfide and total sulfur concentration for withdrawal from the fragmented permeable mass. 14 claims, 4 figures.

Cha, C.Y. Method of Igniting In Situ Oil Shale Retort With Fuel Rich Flue Gas. (to Occidental Petroleum Corp.). US Patent 4,005,752 1 Feb 1977.

A technique is provided for igniting one in situ oil shale retort with flue gas from an earlier retort. Towards the end of oil shale retorting the flue gas from an in situ retort has a substantial fuel value so that it can be burned for generating heat. This fuel gas is conveyed to the entrance to a second retort and burned to initiate retorting. Even after retorting of the bed of particles in the first retort is completed, a fuel rich flue gas can be obtained and used for ignition of a subsequent retort. In either case, the prior retort has a large bed of hot spent oil shale particles through which air is passed to burn carbonaceous material there in. Hot flue gas from the earlier retort can also be used for preheating. 13 claims, 1 figure.

Cha, C.Y. and R.D. Ridley. Enriching Off Gas From Oil Shale Retort. (to Occidental Oil Shale, Inc.). US Patent 4,036,299. 19 Jul 1977.

Liquid and gaseous products are recovered from oil shale in an in situ oil shale retort in which a combustion zone is advanced therethrough by a method which includes the steps of establishing a combustion zone in the oil shale in the in situ oil shale retort and introducing a gaseous feed mixture into the combustion zone in the direction the combustion zone is to be advanced through the in situ oil shale retort. The gaseous feed mixture comprises an oxygen supplying gas and water vapor and is introduced into the combustion zone at a rate sufficient to maintain the temperature in the combustion zone within a predetermined range of temperatures above the retorting temperature of the oil shale in the in situ oil shale retort and sufficient to advance the combustion zone through the in situ oil shale retort. The introduction of the gaseous feed mixture into the combustion zone generates combustion products gases which together with the portion of the gaseous feed mixture which does not take part in the combustion process, is called flue gas. The flue gas passes through the oil shale on the advancing side of the combustion zone, thereby retorting the oil shale to produce liquid and gaseous products. The liquid product and the retort off gas, which comprises gaseous product and flue gas, are withdrawn from the in situ oil shale retort at a point on the advancing side of the retorting zone. 47 claims, 1 figure.

Cha, C.Y. and R.D. Ridley. Process for In Situ Oil Shale Retorting With Off Gas Recycling. (to Occidental Petroleum Corp.). US Patent 3,994,343. 30 Nov 1976.

This process is suitable for in situ retorting of oil shale particles, with retorting proceeding downwardly through a bed of broken pieces of shale. When a single bed is being retorted, air is passed downwardly after ignition until a hot zone trailing the combustion zone has built up to some predetermined thickness, for example, 20 feet having a temperature over 1000°F. Thereafter off gas from the bed is recycled downward without air. Reaction of the recycle gas with the heated spent shale increases the heating value of the resultant off gas. The transfer of heat without combustion increases the yield of oil. When the maximum temperature in the bed drops to a predetermined temperature above the self-ignition temperature of the shale, air is again introduced to reestablish a combustion zone and build up a hot zone. Retorting continues with alternating combustion and recycling periods through the entire bed. When multiple beds of oil shale particles are retorted air is passed downward through one of the beds to maintain a combustion zone until a sufficient hot zone trailing the combustion zone has been produced. Air is then passed through a second bed of oil shale particles and at least a portion of the off gas from the second bed is recycled through the first bed for cooling the hot zone, increasing the heating value of the off gas, and retorting additional oil. Additional beds of oil shale particles can be included in series with combustion zones being intermittently established in each of the beds, alternating with cooling by recycled off gas. 38 claims, 4 figures.

Chew, R.T. III. Operations and Environmental Considerations: Occidental Petroleum Corporation In Situ Operations. pp. 73-81 of In Science and technology of oil shale. Yen, T.F. (ed.). Ann Arbor; Ann Arbor Science Publishers Inc. (1976).

Low-grade material below and within the section selected for mining is broken and mined out, providing space for rubblized ore-grade material. Air, plus recycle gas, is introduced at the top of the broken rubble pile and removed at the bottom. The pile is fired at the top, and the flame front moves forward. Products are oil, light hydrocarbons, water, and carbon. Advantages of the process from the environmental standpoint are discussed.

Closmann, P.J. and M.J. Tham. Producing Shale Oil From a Cavity-surrounded Central Well. (to Shell Oil Co.). US Patent 3,967,853. 6 Jul 1976.

This invention relates to producing shale oil from a subterranean oil shale formation which contains or is contiguous with an areally extensive layer of water-soluble mineral. A plurality of cavities are formed in horizontally spaced locations surrounding a

central well within the subterranean oil shale formation.' Portions of the areally extensive layer of water-soluble mineral are solution mined to form a generally horizontal void that interconnects the cavities and the central well. The shale oil is recovered by circulating hot fluid into the cavities through the void connecting them with the central well and out through the central well.

Closmann, P.J., G. Drinkard, E.H. Street, C.C. Templeton, and M.J. Tham. Subterranean Oil Shale Pyrolysis with Permeating and Consolidating Steps. (to Shell Oil Co.). US Patent 3,945,679. 23 Mar 1976.

In producing shale oil by circulating hot fluid into and out of a rubble-containing cavern within a subterranean oil shale, plugging is avoided by permeating a portion of oil shale, consolidating a permeated portion, inflowing fluid outside the consolidated portion, and outflowing fluid from within the consolidated portion so the fluid is filtered through the consolidated portion.

Church, J.C. Annual Review of Selected Mining Research Activities on the Bureau of Mines. (Bureau of Mines, Washington, D.C. (USA)). Aug 1977. p. 79.

The Bureau's safety R and D program is aimed at providing solutions to problems in all facets of mining. Some of these include fire prevention, suppression, and extinguishment in mines; reduction of explosion hazards through improved personnel safety procedures; degasification and control techniques in high, permeable coalbeds; improved ventilation systems to dilute methane in working areas; roof and rib control to provide inherently safe operating environments; electrical and mechanical improvement relative to safety; underground illumination; emergency communication; refuge chamber installation; emergency hoisting procedures; and techniques for mine sealing following a disaster. Presently the Bureau is engaged in over 200 coal and noncoal safety projects.

Compton, L.E. Method of Oxidizing Hydrogen Sulfide. (to Occidental Oil Shale, Inc.). US Patent 4,086,963. 2 May 1978.

The hydrogen sulfide concentration of a gas is reduced by reacting hydrogen sulfide in the gas with oxygen in the presence of raw oil shale. The ratio of sulfur dioxide to sulfur produced by this reaction depends upon the molar ratio of oxygen to hydrogen sulfide present. Sulfur is the predominant product when hydrogen sulfide is reacted in the presence of oil shale with less than about 1 mole of oxygen for each 2 moles of hydrogen sulfide.

Compton, L.E. and W.H. Rowan. Low Temperature Oxidation of Hydrogen Sulfide in the Presence of Oil Shale. (to Occidental Oil Shale, Inc.). US Patent 4,082,146. 4 Apr 1978.

The hydrogen sulfide concentration of a gas of relatively higher hydrogen sulfide concentration is reduced by combining at a temperature less than about 650°F hydrogen sulfide in the gas with oxygen in the presence of a fragmented permeable mass of particles containing oil shale to yield a gas with relatively lower hydrogen sulfide concentration for withdrawing from the fragmented permeable mass.

Cowles, J.E. and E.M. Boughton. In Situ Recovery of Oil and Minerals from Piceance Creek Basin Oil Shale. (Energy Systems Group of TRW, Inc., McLean, VA). pp. 336-340 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York: American Institute of Chemical Engineers (1976).

An in situ process for recovering shale oil from the salt capped shale deposit at the depocenter of the Piceance Creek Basin in Colorado is discussed. The operations in this process are tailored to this specific deposit. The deposit lies beneath a thick overburden and cannot be economically recovered by conventional mining and surface retorting. The formation is gas tight, free of aquifers and rich in soluble salts, making it a likely candidate site for a successful demonstration of in situ recovery techniques. The salt capped region is estimated to contain over 50 billion barrels of oil in place. The potential oil recovery by this process is 10 to 20 billion barrels of oil. In addition substantial by-product soda ash and aluminium ore are recovered. Details are given on a proposed development program designed to assess the commercial feasibility of the process.

Da Costa Barcellos, E. Process for Obtaining Oil, Gas, Sulfur, and Other Products from Oil Shale. US Patent 4,060,479. 29 Nov 1977. p. 14.

A process is described for obtaining oil, gas, sulfur, and other products from shale whereby there is effected drying, pyrolysis, gasification, combustion, and cooling of pyrobituminous shale or similar rocks in a single passage of the shale continuously in a moving bed. The charge and discharge of the shale is intermittent. The maximum temperature of the bed is maintained in the range of about 1050 to 1200°C or higher. The shale is essentially completely freed from the organic matter, fixed carbon and sulfur, resulting in a clean solid residue which can be disposed of without harming the ecology.

Deering, R.F. Oil Shale Retorting-gasification Process. (to Union Oil Co. of California). US Patent 4,010,092. 1 Mar 1977.

Spent, coke-containing shale derived from a gas-heated eduction zone is passed through a combustiongasification zone countercurrently to an upflowing mixture of steam and oxygen-containing gas

to effect partial combustion of the coke on the spent shale, the resulting heat of combustion being used to effect concurrent endothermic gasification reactions of steam with unburned coke. water gas is then mixed with hot recycle gas derived from the shale reduction zone, the resulting mixture forming the heat carrier required for the gas-heated reduction zone. A recycle portion of the steam-rich water gas from the combustion-gasification zone is continuously withdrawn, passed through a steam generator to effect simultaneous cooling and steam enrichment thereof, and then recycled to the bottom of the gasification reactor. In this manner, a substantial portion of the necessary gaseous heat-carrying capacity is provided in the combustion-gasification zone without losing the heat of vaporization of the steam in the recycle portion of water gas. A surprising aspect of the invention is that even though the recycled water gas contains hydrogen, and must pass through the combustion-gasification zone in which hydrogen-burning temperatures prevail, the overall yield of hydrogen is not significantly affected. 6 claims, 1 figure.

Desborough, G.A. Mineralogy of Oil Shale in the Upper Part of the Parachute Creek Member of the Green River Formation in the Eastern Uinta Basin, Utah. (Geological Survey, Reston, Va. (USA)). 1976. p. 27.

The relative abundance and distribution of major and minor minerals were determined by x-ray diffraction for samples of Green River Formation oil shale in three drill cores from the eastern part of the Uinta Basin, Utah. The samples in each core are from the same rock stratigraphic interval between the Curly bed and Wavy bed tuffs. This interval includes the Mahogany zone, which is the thickest and richest oil-shale unit with the greatest economic potential for extraction of oil. One core is from Naval Oil Shale Reserve No. 2, another is from Federal Prototype Oil Shale Lease Tract Ua, and the third is from an area nominated for a possible federal oil-shale in-situ tract. Dolomite and quartz are generally the most abundant minerals, calcite, albite, and K-feldspar are less abundant. Minor minerals in varied amounts include allite, analcime, aragonite, and smectite. Smectite is abundant in one core and has not previously been recognized in the Mahogany zone. The presence of this mineral is important, inasmuch as it will increase retorting energy requirements. Saline minerals were not detected.

Elkington, W.B. Determining the Locus of a Processing Zone in an In Situ Oil Shale Retort by Sound Monitoring. (to Occidental Oil Shale, Inc.). US Patent 4,082,145. 4 Apr 1978.

The locus of a processing zone advancing through a fragmented permeable mass of particles in an in situ oil shale retort in a subterranean formation containing oil shale is determined by monitoring for sound produced in the retort, preferably by monitoring for sound in at least two locations in a plane substantially normal to the direction of advancement of the processing zone. Monitoring can be effected by placing a sound transducer in a well

extended through the formation adjacent the retort and/or in the fragmented mass such as in a well extending into the fragmented mass.

Elliott, M.A. Gas Industry's Long Range Research and Development Program for Producing Synthetic Fuel Gases. (Texas Eastern Transmission Corp., Houston, TX). pp. 22., Session I, Paper 3 of In Proceedings of the third conference on natural gas research and technology. White, J.W. (ed.). Chicago, IL; Institute of Gas Technology(1974).

A research and development program for producing substitute natural gas (SNG) from indigenous feedstocks has been formulated as a part of the American Gas Association's long range "Gas Industry Research Plan, 1974-2000." The proposed SNG research program includes work on: (1) the production of SNG from coal, heavy oil, oil shale, biomass and solid waste; (2) reaction kinetics and new processing concepts; (3) coal and shale mining; (4) materials of construction in SNG plants; (5) the production of hydrogen from water; and, (6) problems relating to the preservation of the environment in SNG plants. Within each category, specific areas of research are identified and for each of these annual expenditures are recommended for the 1974-1978 period. The estimated cost of the SNG research and development program for that period is about \$1.75 billion which amounts to 77 percent of the entire gas industry's research and development program for the same period. Annual expenditures between 1979 and 1985 are estimated at \$273 million and beyond 1985 at \$254 million. The total funding required to complete all SNG programs is projected to be about \$7.2 billion.

Farberov, I.L. and N.V. Lavrov. Methods of Underground Gasification of Volga Fuel-shales. Translated from Vestn. Inzh. Tekh.; No. 2, 72-74(1940). p. 13.

Plans for the Kuybyshev power plant are considered. As well as the hydro development, a large thermal plant is involved. The only local fuels in this region are fuel shales containing up to 80 percent inert material (ash, moisture, and including carbonates). Volatile products may be up to 70 percent of the fuel mass and nonvolatile carbon is extremely low. The feasibility of underground gasification of this fuel is examined. The high ash and moisture content in the shale and the low content of nonvolatile carbon, with a small seam thickness, create extremely strained thermal conditions for the process. The reduction of relative heat losses by forcing the process is limited, on the one hand, by the low melting point of the ash and, on the other hand, by the impossibility of carrying out the process with melting of the ash, given the horizontal occurrence of Kashpirskii shale seams. The result of all this is that the calculated heating capacity of the gas in an air draft does not exceed approximately 1000 cal/m³. Producer gas of higher calorific value could be made with a steam-oxygen draft or by washing the carbon dioxide out of the gas.

Fisher, S.T. and C.B. Fisher. Extraction of Hydrocarbons In Situ From Underground Hydrocarbon Deposits. US Patent 4,008,762. 22 Feb 1977.

A method is described of extracting hydrocarbons in situ from an underground hydrocarbon deposit such as oil shale. A selected part of the deposit is heated by one or more electrical induction coils arranged in a quasi-toroidal configuration to temperatures high enough to drive off hydrocarbon fractions as gases or vapors, which are then collected and utilized in surface operations or recovered for transportation or temporary storage. The deposit may optionally be heated through a coking and cracking stage. Any remaining hydrocarbons may be burned in situ and the combustion gases utilized for energy. Steam may be obtained by injecting water into the heated shale after extraction of the hydrocarbons.

French, G.B. and D.E. Garrett. Multiple Zone Preparation of Oil Shale Retort. (to Occidental Oil Shale, Inc.). US Patent 4,043,598. 23 Aug 1977.

A subterranean deposit containing oil shale is prepared for in situ retorting by initially excavating a plurality of vertically spaced apart voids of similar horizontal cross section located one above another within the deposit. A plurality of vertically spaced apart zones of unfragmented deposit are temporarily left between the voids, each unfragmented zone having a thickness of less than about 190 percent of the smallest lateral dimension of the voids above and below it. Explosive placed in each of the unfragmented zones is detonated, preferably in a single round to expand each unfragmented zone into the voids on either side of it and form a subterranean room containing a fragmented mass of particles having a void volume equal to the void volume of the initial voids. Retorting of the expanded mass is then carried out to recover shale oil from the oil shale.

French, G.B. and R.D. Ridley. Method of Enhancing Recovery of Oil From Pillars Adjacent In Situ Oil Shaft Retort. (to Occidental Petroleum Corp.). US Patent 4,025,115. 24 May 1977.

An underground in situ oil shale retort is described which contains a bed of fragmented oil shale particles having an appreciable void volume. Air or other retorting gas passed through this bed of fragmented oil shale supports combustion of some of the carbonaceous material in the oil shale and provides heat for retorting the oil. A number of such retorts may be formed in an area and pillars are left to support the overburden. Pillars forming walls between adjacent retorts also prevent gas leakage. Oil recovery from intact oil shale pillars between retorts is enhanced by fracturing the pillars as well as fragmenting the shale in the retort. The pillars are fractured by detonating explosives in bore holes in the region between the retort and pillars, preferably a fraction of a second after explosive fragmentation of the oil shale in the retort. 24 claims, 4 figures.

French, G.B. Method of Recovering Oil and Water From In Situ Shale Retort Flue Gas. (to Occidental Oil Shale, Inc.). US Patent 4,029,360. 14 Jun 1977.

A technique is described for reducing the content of oil and water in the flue gas recovered from the bottom of an underground in situ oil shale retort. In such a retort air is passed downward to sustain a combustion zone for retorting oil which is recovered at the bottom. Flue gas recovered from the bottom of the retort contains water vapor and oil and water aerosols. These are removed from the flue gas by passing it a substantial distance upwardly through cool overburden so that the flue gas is cooled below its dew point so that water condenses in the vertical conduit and aerosols are dropped out on the walls. The oil and water are recovered at the bottom of the conduit and stored in an underground sump. 5 claims, 1 figure.

French, G.B. Multiple Level Preparation of Oil Shale Retort. (to Occidental Oil Shale, Inc.). US Patent 4,043,597. 23 Aug 1977.

A subterranean deposit containing oil shale is prepared for in situ retorting by initially excavating a plurality of vertically spaced apart voids of similar horizontal cross section located one above another within the deposit. A zone of unfragmented deposit temporarily left between each adjacent pair of voids has a thickness greater than the smallest lateral dimension of the voids above and below it. Explosive placed in a lower portion of the unfragmented zone is detonated to expand the lower portion of the unfragmented zone into the lower void, leaving the upper portion of the zone intact and creating a space free of fragmented particles below it. Thereafter, the remaining portion of the unfragmented zone is explosively expanded into the open space below it and into the upper void, forming a subterranean room filled with a fragmented mass of particles having a void volume substantially equal to the total initial volume of the voids. Retorting of the expanded mass is then carried out to discover shale oil from the oil shale.

Frost, C.M., R.E. Poulson, and H.B. Jensen. Production of Synthetic Crude from Crude Shale Oil Produced by In Situ Combustion Retorting Am. Chem. Soc., Div. Fuel Chem., Prepr.; 19: No. 2, 156-168 (1974).

A premium synthetic crude oil was produced by catalytic hydrogenation of an in situ crude shale oil after selection of a suitable catalyst. The processes are described.

Garrett, D.E. Fracturing of Pillars for Enhancing Recovery of Oil from In Situ Oil Shale Retort. (to Occidental Oil Shale, Inc.). US Patent 4,045,085. 30 Aug 1977.

An underground in situ oil shale retort, having predetermined boundaries, contains a bed of fragmented oil shale particles having an appreciable void volume distributed therethrough. Air passed through this bed of fragmented oil shale supports combustion of some of the carbonaceous material in the oil shale and provides heat for retorting oil therefrom. A number of such retorts may be

formed in an area and pillars are left to support the overburden. Pillars forming walls between adjacent retorts also prevent gas leakage. Oil recovery from intact oil shale pillars is enhanced by fracturing the pillars as well as fragmenting the shale in the retort. The pillars are fractured by hydraulic fracturing, electrical fracturing, liquid explosive fissuring, or the like. The fractures are propagated from access holes in the vicinity of the pillars, typically between similar holes adjacent the next retort volume when the pillars are between retorts. 26 claims, 4 figures.

Green, L. Jr. Hydroretorting of Oil Shale with Nuclear Process Heat. New York; American Society of Mechanical Engineers (1976).

This paper proposes a concept by which utilization of nuclear process heat from a high-temperature gas-cooled reactor (HTGR) for above-ground and in situ hydroretorting of oil shale using the Institute of Gas Technology process can conserve that fraction of the hydrotreated syncrude product which would otherwise have to be burned for fuel. In addition to providing process heat at an estimated cost lower than that projected for shale oil combustion, the HTGR also avoids environmental problems of air pollution and water requirements which attend the mining and burning of coal, and other alternative energy sources. When the economic advantage of nuclear heat over oil heat is lost due to the in situ retorting sites moving too far away from the heat source, the process equipment is removed and the process plant converted to a power plant. If the limiting distance from the plant site is 1.5 miles, the useful life of the process plant prior to conversion is estimated to be approximately 20 years, the amortized lifetime of the process equipment.

Haaland, D.M. Development of a Solid-electrolyte Oxygen Sensor for In Situ Oil Shale Retorting Applications: Final Report. (Sandia Labs., Albuquerque, N.Mex. (USA)). Mar 1978.

A new solid-electrolyte oxygen sensor has been developed suitable for air-fired in situ oil shale retorting applications. By eliminating the flowing gas reference of conventional solid-electrolyte sensors, only electrical leads to the surface are required for oxygen monitoring. The new design consists of two electrochemical cells of stabilized-zirconia solid electrolyte sealed into a small unit. One electrochemical cell monitors the ratio of oxygen partial pressures inside and outside the sensor while the second cell is used as a quantitative electrochemical oxygen pump. The initial measurement procedure requires that all oxygen be electrochemically removed from the known internal volume of the sensor by applying a potential across the second cell. The polarity of the potential is then reversed so that oxygen from the surrounding gas is electrochemically pumped back into the sensor. When the EMF of the first cell reaches zero, the oxygen partial pressure inside the sensor is equal to that of the surrounding gas. Integrating the current required to achieve this condition yields the number of moles of oxygen pumped into the sensor. This information is used

in the ideal gas law to calculate oxygen partial pressures. Tests of these sensors were conducted from 400 to 1000°C in clean mixtures of oxygen and nitrogen spanning about 0.1 to 21% oxygen concentration range with reasonable accuracy. Tests in non-equilibrium gas mixtures of combustible gases in the presence of oxygen indicated significant catalytic reaction at the surface of the platinum electrodes. Thus accurate bulk gas phase oxygen measurements could not be made with sensors using pure platinum electrodes. Extensive studies of a variety of less catalytic electrode materials were made. The best results were obtained using a 50/50 mixture of PbS/Pt over sputtered platinum. These electrodes were non-catalytic above approximately 550°C.

Hendrick, R.P. Recovery of Hydrocarbons by In Situ Thermal Extraction. US Patent 3,954,140. 4 May 1976.

Hydrocarbons are recovered from a subterranean formation by providing a plurality of generally horizontal boreholes in the formation. The boreholes are vertically spaced across the thickness of the formation and extend from the top to the bottom thereof. Selected boreholes are heated by means of an external source to drive off hot hydrocarbon gases. The hot gases are fed to selected, unheated boreholes to effect a preheating of the selected boreholes and to cool the hot gases prior to their recovery from the formation.

Hubbert, M.K. Outlook for Fuel Reserves. (Geological Survey, Reston, VA). pp. 11-23 of In Encyclopedia of energy. Lapedes, D.N. (ed.). New York: McGraw-Hill Book Company (1976).

An examination of Earth's energy systems shows that the main influxes into the surface environment are from solar radiation, tidal energy, and terrestrial energy (especially geothermal). A portion of the solar power (40×10^{12} W) is captured by the green leaves of plants and used in the process of photosynthesis. This then becomes the basic energy source for the physiological requirements of the entire plant and animal kingdoms, including the human species. Nearly all plant and animal material decays to its original constituents and the stored energy is released as heat. But minute quantities of biological materials that have become deposited in peat bogs or other oxygen-deficient environments have been transformed into the earth's present supply of fossil fuels. Exploitation of world and USA fossil fuels is discussed. P. Averitt in 1969 estimated recoverable coal as 7.64×10^{12} tons for the world and 1.486×10^{12} tons, or 19 percent of the world total for the USA. Since these estimates included very great depths and very thin seams, Averitt revised these estimates (in 1972) to 2.0×10^{12} metric tons worldwide and 390×10^9 metric tons for the USA. Hubbert then explains his production cycle curves for crude oil, natural gas, and their products. Other data are provided for tar sands, oil shale, and solid hydrocarbon gilsonite.

Huc, A.Y. Geochemical Provinces Revealed in Toarcian Oil Shales in the Eastern Paris Basin. Analysis of the Soluble Organic Fraction. (Univ Louis-Pasteur, Strasbourg, Fr). Rev. Inst. Fr. Pet. Ann. Combust. Liquides; 31: No. 6, 933-53(Nov-Dec 1976).

An analysis of soluble organic matter in the chloroform from Toarcian shales reveals the existence of a northern geochemical province and a southern geochemical province whose common boundary lies in the Fecocourt region. The northern province is characterized by the influence of the continental domain (Ardennes range) with regard to organic influx, whereas no terrestrial influx is found in the southern province. These findings agree with the sedimentological indications supplied by the literature and add a geochemical dimension to the paleogeography of this basin. 30 ref.

Jee, C.K., J.D. White, and S.K. Bhatia. Study of True In Situ Oil Shale Technology. (Booz-Allen Applied Research, Inc., Bethesda, Md. (USA)). May 1977.

This study is a technical review and economic analysis of current true in situ oil shale technology. Three techniques are compared involving different fracturing methods, focusing on the technical and economic variables common to the technique. The key variables identified and investigated include air compression, drilling depth, drill hole diameter and pattern geometry, shale grade, shale bed thickness, and explosives requirement. In addition, engineering R and D needs related to the variables are identified and documented. The appropriate variables, process systems, and process steps defined for each fracturing technique are scaled up to a 64,000-bbl/day facility and costed to provide a basis for evaluating relative economic feasibility. Capital investment, capital depreciation, annual operating, and crude shale oil costs are estimated and compared based on the scale-up scenarios. The economic evaluation reveals that the choice of fracturing technique does not have any significant effect on the crude oil shale price estimated for the scaled-up facilities. The combination of hydraulic fracturing and explosive rubblelization is postulated to have the best potential for improvement. High costs associated with compression of the injection gas and drilling may strongly influence process economics. The actual amount of oil recovered or extracted from the shale is also a major economic factor. The study concludes that the logistics of a commercial operation and the inability to create adequate permeability and surface area by each of the three fracturing techniques evaluated appear to be limiting factors.

Johnson, W.F. and T.H. Timmins. Heat Transfer and Product Formation During the In Situ Retorting of Oil Shale. (Mobil Research and Development Corp., Dallas). pp. 169-178 of In Resource recovery. Albuquerque, NM; American Society of Mechanical Engineers (1975).

For in situ retorts in which a bed of rubblelized oil shale is retorted using an oxygen-containing gas, there are two zones of major significance. The upstream zone is the combustion zone, the down-

stream zone is the retorting zone. The movement of these zones through the retort is generally described as the rate of combustion front advance or the rate of retorting front advance. Model studies indicate that under some conditions the combustion front will move more slowly than the retorting front and separation of these fronts will occur. Using a given retort operated under conditions of constant rate of heat loss to its surroundings, constant oxygen flux and constant fuel concentration, the combustion front advance rate increases monotonically with the mass average particle size of the shale charge. Yield calculations show the necessity of optimizing the combustion front advance rate as a function of particle size distribution. One apparent way to increase shale oil yield in an in-situ retort is to generate a rubble bed having a smaller particle size distribution than mine-run shale and then increase the shale heat-up rate by increasing the gas flux.

Knight, J.H., L.A. St. Cyr, and O.L. Wilson. Recovery of Hydrocarbon Values by Controlled Eduction and Oxidation of Oil Shale. (to Superior Oil Co.). US Patent 4,082,645. 4 Apr 1978.

In the process for recovering energy values from oil shale by the cross-flow retort technique, an improvement is disclosed wherein controlled oxidation of nonvaporizable carbonaceous residue not only provides additional heat for the continuation of the oil educing process without application of external heat but also enables the continuation of a temperature profile which is below that at which adverse chemical and physical changes occur in the shale. According to the invention the moving bed is removed from exposure to external heat as soon as oil eduction has been completed in the upper bed regions. It is hereafter immediately exposed to unheated gases containing measured amounts of oxygen. Oxidation is initiated in those regions of the bed which are above about 800°F. The heat generated by such oxidation may be utilized, in place of externally heated gases, to transfer heat to the lower regions of the bed for oil eduction from those lower regions.

Lekas, M.A. Process for Recovery of Carbonaceous Materials From Subterranean Deposits by In Situ Processing. US Patent 4,037,657. 26 Jul 1977.

Subterranean carbonaceous deposits, such as oil shale or the like, that are located at or close to the surface, are prepared for retorting by drilling blast holes from the surface into the deposit, and blasting, creating a rubble pile that reaches the surface. The surface is sealed by suitable means, and the oil shale is retorted in place. Where a stratum of barren rock lies between the carbonaceous deposit and the surface, the blast holes are drilled and blasted in such a manner as to maximize the fragmentation of the carbonaceous deposit, and minimize the fragmentation of the overlying barren stratum. Where overburden conditions are not suitable for treatment by this method, the overburden is removed by strip mining methods, and the carbonaceous deposits are exposed for treatment by the method described above. 16 claims, 8 figures.

Lewis, A.E. and A.J. Rothman. Modified In Situ Oil Shale Technology at the Lawrence Livermore Laboratory: Experimental Results and Present Status. (Univ. of California, Livermore). 1977

An experimental effort is in progress to obtain a comprehensive understanding of the oil shale retorting process. Recent results have increased understanding of the mechanism of yield loss, the decomposition of carbonate minerals, and the reaction of char with O_2 and CO_2 . A computer model has been compared successfully with retort experiments and is proving useful in optimizing the process and in designing further experiments.

Littlewood, K. Gasification: Theory and Application. (Univ. of Sheffield, Eng.). Prog. Energy Combust. Sci., 3: No. 1, 35-71(1977).

Processes for the gasification of coal, oil shales and various petroleum feedstocks are reviewed in depth: history, chemical reactions, thermodynamics, and brief descriptions of particular processes. The production of hydrogen, ammonia, methanol and other chemicals from synthesis gas are discussed. Simplified flowsheets are given in many cases.

Long, A. Jr., N.W. Merriam, C.E. Mones, and L.J. Romanowski. Some Results from the Site 9 In Situ Oil Shale Experiment at Rock Springs, Wyoming. (Energy Research and Development Administration, Laramie, WY). 1977

The paper presents results of the first 150 days of in situ retorting of oil shale at site 9 near Rock Springs, Wyo. A 70-foot (21.4 m) square of 21.3 gpt (89 liters pmt) oil shale in the Green River Formation was explosively fractured. Following the ignition on April 5, 1976, the combustion front was monitored with a computer based data acquisition system which reported conditions hourly. Nitrogen balances showed average gas recovery of 93 percent with an average oxygen utilization of 65 percent. Material balance calculations indicated 3,260 tons (2,964 m tons) representing 21 percent of the oil shale was retorted. Oil migration beyond the recovery area was evidenced and only 2,483 gallons (9,300 liters) of shale oil was recovered. Low Btu gas produced had a total calorific value of 1,515 million Btu (382 million Kcal). Environmental studies of effects on air, ground surface, and ground water were conducted. A complete evaluation of the test will be made after core samples are taken.

Loucks, R.A. Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale: Phase I. Summary Report, November 1, 1976-October 31, 1977. Volume I. (Occidental Oil Shale, Inc., Grand Junction, Colo. (USA)). Nov 1977.

Since early 1973, Occidental Oil Shale, Inc. (OXY) has processed three small-scale modified in situ retorts (Retorts 1E, 2E, and 3E) in their Research Mine, and is currently processing the second

large-sized retort (Retort 5) in their Development Mine, both mines being located on OXY's D.A. Shale property northeast of DeBeque, Colorado. Progress of the project since November 1, 1976 is summarized starting with the pre-blast activities and the startup for Retort 5, through the mining progress in the formation of Retort 6. The environmental aspects including the required permits are discussed along with the geology and hydrology data from the C-b tract. Results of various studies on potential markets for shale oil are presented and the schedules presented in OXY's proposal to ERDA are compared with the schedules achieved through October, 1977. A section is included on future plans.

Loucks, R.A. Occidental Vertical Modified In Situ Process for the Recovery of Oil From Oil Shale: Phase I. Summary Report, November 1, 1976-October 31, 1977. Volume II. (Occidental Oil Shale, Inc., Grand Junction, Colo. (USA)). Nov 1977.

A listing of the plant species (the flora) and an assessment of their relative amounts in various areas (the vegetation) have been compiled for the Occidental Oil Shale, Inc. property near DeBeque, Colorado. One hundred eighty-four species of higher plants have been found on the property. These include 7 trees, 25 shrubs, 16 grasses, 134 forbs, and 2 succulents. Ninety-one percent of these species are native to the area. Ten types of vegetation were identified following collection and statistical analysis of cover, density, and frequency data from systematically arranged plots. The importance of these types, the soils and landforms associated with them, and major estimates of response to development are discussed by vegetation type. The use of each of these types by livestock and game animals has also been indexed. Of particular importance to science and oil shale development is the occurrence of two species (*Astragalus lutosus* and *Festuca dasyclada*) on the Smithsonian's rare and endangered species list. The grass (*Festuca*) occurs at one known site on the Mohogany Ledge at a location far away from present or planned surface disturbances. It was thought to have been extinct. The locoweed (*Astragalus*) is previously known from Rio Blanco County and is also present on other oil shale properties. It is urged that care be taken in constructing roads and muck dumps so that brushy vegetation is not smothered; it is needed to hold soil in place and thereby prevent excessive land slumping and erosion.

Lyczkowski, R.W., C.B. Thorsness, and R.J. Cena. Use of Tracers in Laboratory and Field Tests of Underground Coal Gasification and Oil Shale Retorting. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 16 Jun 1978.

Tracers have recently been suggested for laboratory and field experiments of simulated and actual underground retorting of coal and oil shale. The intended use of laboratory and field retort testing is examined, and found to be mainly for estimation of properties of the flow field. The field implementation, data

reduction procedure and preliminary results of helium tracer work at Hoe Creek II coal gasification experiment are presented. It was found that the active void volume calculated from the tracer data generally agrees with the consumed coal volume determined from material balances. One and two-dimensional dispersion models predict a highly dispersive system. This review of tracer theory and its usual laboratory application has served to point out its limitations and proper usage. The usage of tracer theory in laboratory and field tests of UCG and oil shale retorting was found to include: generation of information on the flow properties; determination of the total amount of active void volume; determination of the dispersiveness of the injected gas; and analysis of flow channeling and fissuring. At this time lack of knowledge of the flow field needed for interpreting the tracer experiments makes the analysis difficult. In order to understand the tracer data, a theory involving the solution of an inverse problem needs to be developed.

Lytle, R.J. and G.K. Myers. Temperature-profile Determination Using Frequency-domain Reflectometry.

The temperature distribution along a coaxial electrical cable can be determined by means of frequency-domain reflectometry if the cable has an inner sheath of a suitable temperature-sensitive dielectric material. Such a technique would have advantages in cost and convenience over the conventional method of placing a separate thermocouple at each point where the temperature is to be measured. It would be especially useful for underground applications in assessing geothermal reservoirs and in instrumenting in situ coal-gasification and oil-shale-retorting experiments.

Marland, G., A.M. Perry, and D.B. Reister. Net Energy Analysis of In Situ Oil Shale Processing. (Oak Ridge Associated Universities, TN). Energy (Stanford, Conn.); 3: No. 1, 31-41(Feb 1978).

Although the domestic resources of shale oil are large, there has been some question regarding the magnitude of the energy subsidy that must be committed in order to extract the contained oil. This study shows that for a 50,000 b/d, modified in situ extraction facility in 20-gal-per-ton Green River Shale, the energy yield is about 8.6 times the energy subsidy and that about 21 percent of the in-place oil can be thus recovered. If the mined-out shale is retorted at the surface rather than being discarded, the recovery factor rises to 37 percent and the net energy ratio should rise significantly as well. It is difficult to compare these figures with those for aboveground retorts because oil burned in place for retorting never enters the energy accounts. However, the resource commitment per unit of recovered energy is more easily compared and is essentially indicated by the reciprocal of the recovery fraction.

Maugh, T.H. Oil Shale: Prospects on the Upswing...Again. Science; 198: No. 4321, 1023-1027(9 Dec 1977).

Conditions look good for the in situ conversion and surface retorting of oil shales. The difficulty of fracturing the shale is alleviated by using the modified in situ process, in which about 20% of the shale is first mined out. Surface retorting is also under development. The problem of high N, S, and paraffinic waxes in the shale oil may be solvable by hydrogen treatment. Environmental impacts appear manageable; restrictive air quality standards are being eased. Ammonia and elemental sulfur could be recovered as by-products. A mix of surface, in situ, and modified in situ retorting might be able to produce 2 to 3 million bpd by 2000.

McCarthy, H.E. Effect of Combined Modified In Situ/above Ground Processing of Oil Shale. (Oil Shale Industry Development Co., Bakersfield, CA). 1977.

The effect of combining the modified in situ process with an aboveground retorting of the mined shale is discussed. A parametric study showing the effect of mining different zones and the overall resource recovery is given. Using published numbers, an attempt is made to show the advantages of the combined processes.

McCarthy, H.E. and C.Y. Cha. Oxy Modified In Situ Process Development and Update. (Occidental Exploration and Production Co., Bakersfield, CA). Q. Colo. Sch. Mines; 71: No. 4, 85-100(Oct 1976).

Various stages in the development of the Occidental Petroleum Corp. modified in situ process are summarized. Three small-scale in situ retorts have been successfully tested. It was demonstrated that the method could be applied to a large-scale retort, that the large-scale retort's performance can be predicted, and that modification to the retorting parameter can be calculated. At present, avenues of commercialization of the process are being investigated.

McIntyre, H. Oil Shale Recovery Poses Energy Supply Questions. Energy Int.; 15: No. 5, 30-32(May 1978).

Imperial Oil Ltd of Canada is negotiating to begin extracting oil sands from an Alberta project that could yield 145,000 barrels a day. Covered by several hundred feet of overburden, the deposits are too deep for the surface mining techniques used at other oil sands projects. An experimental steam injection process which uses wells to heat the deposits and permits recovery of the hydrocarbon portion has been demonstrated for several years. The new project will entail enlarging and upgrading the prototype. Energy and water requirements will make the process one of the world's most energy-intensive in spite of conservation efforts. Project planners must choose between using the liquid-bitumen feed, coal, or nuclear energy as fuels for heating the deposits. If liquid plant feed is

used, the net output will be reduced nearly 20 percent. Of the 900,000 barrels of water needed daily, process water will be recycled and residual water injected into underground formation. A "Flexicoking" process will be used to draw up the oil and gasify the coke output. Recent taxes to ensure world price levels for heavy oils will require further negotiations between the oil company and the Alberta government.

Needham, R.B., A. Judizis, Jr., and A.J. Cornelius. Oil Yield and Quality from Simulated In Situ Retorting of Green River Oil Shale. New York; American Institute of Mining, Metallurgical, and Petroleum Engineers (1976). p. 12.

The yield and quality of shale oil produced for in situ retorting conditions was measured by laboratory experiments and related to shale particle size, retorting temperature, and heating rate. In situ retorting with recycle shale gas at a temperature of 800°F should result in an oil yield of 80 to 85 weight percent of Fischer assay. The in situ retorted oil would contain 1.7 to 2.0 weight percent nitrogen and 0.5 to 0.7 weight percent sulfur; these values are typical of shale oil from the conventional gas combustion retort. The in situ retorted oil will have a slightly higher API gravity and be more volatile than oil produced by the gas combustion retort because of additional thermal cracking during production from the larger particles. The oil yield and nitrogen content of the oil did not depend upon the shale particle size for retorting temperatures up to about 800°F, but at higher retorting temperatures, the oil yield was markedly lower for the larger particles. Therefore, in situ retorting temperatures should be less than about 800°F.

Nuttall, H.E. Mathematical Modeling and Experimental Investigation of In Situ Oil Shale Retorting. Dallas; American Inst. of Mining, Metallurgical, and Petroleum Engineers (1976). p. 16.

An experimental investigation of oil shale retorting is presented. The apparatus and operating conditions presented were designed specifically to simulate the in situ vertical fractured bed retorting process. The dependent retorting variables (oil yield, retorting rate, and bed weight loss) were investigated in terms of six process variables (gas content). Multiple linear regression analysis was used to determine the significance and rank of each variable. In addition, extensive temperature profile measurements were recorded and are presented from several of the more recent tests. Temperature profiles are illustrated graphically in two forms; as two-dimensional time/temperature profiles and as three-dimensional thermo-response surfaces. A mathematical formulation of the experimental retort is presented and modeling results are discussed.

Perry, A.M., W.D. Devine Jr., A.E. Cameron, G. Marland, H. Plaza, D.B. Reister, N.L. Treat, and C.E. Whittle. Net Energy Analysis of Five Energy Systems. (Oak Ridge Associated Universities, Inc., Tenn. (USA)). Sep 1977.

A net-energy analysis is performed for each of five developing energy technologies: ocean thermal energy conversion, wind energy conversion, in situ oil shale processing, fluidized-bed coal combustion, and municipal solid-waste utilization. Energy expenditures required during construction and life long operation and maintenance are estimated using input-output and process analyses. These expenditures, including both direct and indirect consumption, are classified as capital or operating expenditures and as expenditures for electric or nonelectric inputs to the systems. Various ratios that compare the anticipated energy product of a system to its estimated energy subsidy are defined. It is not, in general, possible to compare dissimilar technologies on the basis of these performance indices. However, the indices do indicate all of the systems considered here are net producers of energy and decisions to proceed with development and deployment should be based on other considerations.

Peterson, C.R. Mechanized Mining and In Situ Retorting of Oil Shale. (Massachusetts Inst. of Techn., Cambridge). pp. 5B1.1-5B1.6 of Energy resources and excavation technology. Wang, F.D., and G.B. Clark. (eds.). Golden, CO; Colorado School of Mines(1977).

The Rapidex SAM, for Self-Advancing Miner, as applied to oil shale mining is discussed. The purposes are twofold: to present interesting machine excavation concept and its possible applications; and, more generally, to illustrate the kind of mine-mining machine design process that will be necessary to meet requirements. A particular example of the potential benefits of combined mine and mining machine design is presented. As in any design discussion it is necessary to speak in terms of specific concepts in order to convey the general philosophy of the design process. The important message, then, is not in the particulars of the machine or the retorting scheme, but rather in the interrelations between the various elements of the system which can be exploited if simultaneously considered. In the past, a machine designer produced a jackhammer which, in the hands of a skilled operator and under the direction of an experienced mining engineer, could be used to drill and blast virtually any mine geometry desired: there was complete decoupling of machine and mine design. As mechanized mining develops, the decoupling will not be possible.

Poulson, R.E., C.M. Frost, and H.B. Jensen. Characteristics of Synthetic Crude from Crude Shale Oil Produced by In Situ Combustion Retorting. (Laramie Energy Research Center, WY). Adv. Chem. Ser.; No. 151, 1-10(1976).

A synthetic crude prepared by hydrogenating the naphtha, the light oil, and the heavy oil fractions obtained from in situ crude shale oil by distillation and coking of the 850°F + residuum was characterized by examining the fractions. The heavy oil had 935 ppm

nitrogen of which 40 percent was pyridine-type nitrogen, and 60 percent was pyrrole-type nitrogen. The light oil had 79 ppm nitrogen, all of which was pyridine-type nitrogen. The naphtha had less than 1 ppm nitrogen, which was not characterized. The saturate content of the fractions was-naphtha, 87 percent; light oil, 77 percent; and heavy oil, 73 percent. In addition, the heavy oil contained 6 percent olefins and 2 percent polar material.

Prats, M., P.J. Closmann, A.T. Ireson, and G. Drinkard. Soluble Salt Processes for In Situ Recovery of Hydrocarbons from Oil Shale. Dallas; American Inst. of Mining, Metallurgical, and Petroleum Engineers (1976). p. 20.

In the central portion of the Piceance Creek in Colorado, certain soluble salts occur in intimate association with the oil shale. The shale oil resource in this area of the Piceance Creek Basin is very large, some 50 to 100 billion barrels in place, on a Fischer Assay basis. This paper describes a class of in situ shale oil recovery process in which permeability and porosity are developed by dissolution of these soluble salts. These processes consist of two steps which may be conducted simultaneously or sequentially: (1) leaching of soluble salts, and (2) conversion of kerogen. Although steam pyrolysis is emphasized as a possible means of conversion, combustion and hot gases are suggested as alternatives. These processes differ in two aspects from recovery processes used in oil reservoirs: (1) the permeable system developed by leaching is confined by essentially impermeable boundaries, and (2) the hydrocarbon (kerogen) present is in the solid form and must be converted to a liquid or gas before it can be produced. A field test of a steam conversion process was conducted by Shell Oil Company in 1970-72 in the Piceance Creek Basin. This test generated a sizable permeable volume in the subsurface, confinement was maintained, and kerogen was converted. The conduct of the test and some of the problems that developed, such as productivity impairment and corrosion of tubulars, are discussed in this paper.

Prien, C.H. Current Developments in Oil Shale Processing. (Denver Research Inst.). 1977.

Presently available technology for producing shale oil from western U.S. oil shale deposits includes both surface retorting and in situ processing. Five surface processes, viz TOSCO II, Paraho, Union B, Superior, Lurgi, have been operated at either the pilot plant or semi-works level. Increasing emphasis is being placed on both true in situ and modified in situ methods, because of their apparent lesser environmental impacts and potentially lower costs. Developments are occurring on both government lease sites and private lands. The high investment costs involved are a formidable barrier to early creation of a U.S. shale oil industry.

Raley, J.H., W.A. Sandholtz, and F.J. Ackerman. Results from Simulated Modified In Situ Retorting in Pilot Retorts. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 1978.

Data obtained from operating 1.5 m x 0.3 m and 6 m x 0.9 m laboratory retorts to simulate a modified in situ process are summarized. The effects of feed-gas composition, including addition of steam, shale particle size and bed porosity on retorting rate, temperature maxima and profiles, off-gas composition and oil yield are presented. Inclusions of steam is shown to increase retorting rate, oxygen efficiency and hydrogen content of the off-gas. The heating value of the off-gas is also raised somewhat, but is mainly determined by the C_4+ content. With a narrow shale particle size range, the experimental data agree well with model calculations based on the underlying physical and chemical processes. The experimental results with a broader range of particle size or large content of fines indicate complexities due to gas flow non-uniformity and oil holdup. The use of intra-retort gas composition and temperature data to detect and help interpret these complexities is demonstrated.

Reed, T.G. Jr. Process for Treating Oil Shale. US Patent 3,939,057. 17 Feb 1976.

A process for producing a crude shale oil and a high BTU gas comprises feeding a mixture of a major amount of crushed oil shale and a minor amount of coal, sufficient to provide process heat which is needed in excess of that supplied by burned char, to a rotary preheater, heating said mixture to a temperature less than that at which decomposition of kerogen begins (said heating by direct contact of said mixture with a flow of hot gases), passing said preheated mixture to a rotary retort, indirectly heating said mixture to a temperature in the range of 850 to 1050°F with said hot gases. These hot gases indirectly heat said rotary prior to contacting said mixture in said preheater, taking off a vaporous overhead comprising shale oil and tar oil and leaving a char on said shale, passing the retorted mixture to a hopper, then removing residual shale oil by sweeping said hopper with superheated steam. The vaporous overhead and stripped shale oil residual are passed to a high temperature condenser, condensing an oil fraction at a temperature above 212°F from said vaporous overhead and said hopper residual shale oil, then passing the uncondensed gases from the high temperature condenser to a low temperature condenser, condensing water from said uncondensed gas, recovering a high BTU gas, passing said mixture from the hopper to a furnace, and burning said char and unvolatized coal to produce said hot gases. These pass from said furnace, first contacting said rotary retort and then directly contacting the mixture in the preheater.

Richmond, C.R. Testimony Presented to the U.S. Environmental Protection Agency's Public Hearing on Environment and Conservation in Nonnuclear Energy Research and Development, March 31, 1978, Washington, D.C. (Oak Ridge National Lab., Tenn. (USA)). May 1978.

The author cites Public Law 92-577, The Nonnuclear Energy Research and Development Act of 1974, as mandating this Public Hearing as a forum to review the adequacy of emphasis on energy observation and environmental implications of the Federal energy R, D and D program. President Carter directed ERDA (now DOE) and EPA in May 1977 to jointly develop procedures for establishing environmental protection standards for all new energy technologies and asked that the procedures be agreed upon within one year. The author first discusses general issues before he specifically addresses the the subject of oil shale and synthetic fuels from coal. Specific issues on availability of these fuel technologies, impacts of implementation, and management of synthetic fuel technologies are discussed. Two broader issues are discussed. One concerns our national difficulty in arriving at a broad consensus on acceptable tradeoffs between environmental protection and other goals of society such as the important ones of achieving energy independence and avoiding energy shortages. The second is the question of the Federal role in a situation where a vast number of impacts and decision makers are either local, state, or regional in scale.

Ridley, R.D. Forming Shale Oil Recovery Retort by Blasting Into Slotshaped Columnar Void. (to Occidental Oil Shale, Inc.). US Patent 4,043,596. 23 Aug 1977.

An in situ oil shale retort is formed in a subterranean oil shale deposit by excavating one of more slot-shaped columnar voids each having a pair of vertically extending, planar free faces, drilling blasting holes adjacent to the columnar void and parallel to the free faces, loading the blasting holes with explosive, and detonating the explosive in a single round to expand the shale adjacent to the columnar void, one directionally toward each free face in one or more planar layers severed in a sequence progressing away from each free face, and to fill with fragmented oil shale the columnar void and the space in the in situ retort originally occupied by the expanded shale prior to the expansion. The pair of free faces extend across the entire width (or length) of the retort being formed. A room having a horizontal floor plan that coincides approximately with the horizontal cross section of the retort to be formed is excavated so as to intersect the columnar void. The blasting holes are drilled and loaded with explosive from the room.

Ridley, R.D. Oil Collection and Recovery System for In Situ Oil Shale Retort. (to Occidental Petroleum Corp.). US Patent 4,007,963. 15 Feb 1977.

An in situ oil shale retort is provided with a sealed space at the bottom in which liquids produced in the in situ retort and retort off gases are separated. The separated liquids and retort off gases are removed from the sealed space through a bulkhead provided in an access tunnel leading to the sealed space which can be a portion of the tunnel. A sump is provided in the floor of the

access tunnel inside the sealed space for collecting liquids. Trenches extending from the bottom of the in situ retort into the sump are provided for directing liquids from the in situ retort to the sump. The trenches are backfilled with large shale particles to prevent blocking of the trenches when the oil shale in the retort is explosively fragmented. Conduits extending through the bulkhead and into the sealed space are provided for removing liquids from the sump and retort off gases from the sealed space above the liquid level. 16 claims, 2 figures.

Ridley, R.D. Process for Effecting Even Retort Working Fluid Flow Throughout an In Situ Retort Containing Carbonaceous Deposits. (to Occidental Petroleum Corp.). US Patent 3,951,456. 20 Apr 1976.

The rubble pile in an in situ reactor, which has a low length-to-diameter ratio and limited retorting gas inlets and outlets, has a radial bulk permeability distribution controlled to provide retort working gas flow paths from the inlets to the outlets with substantially even overall flow resistance. Channeling of retort gas along paths of low resistance is therefore avoided. An example of the controlled radial distribution of bulk permeability is a cylindrical, vertical in situ retort having a retort gas inlet and outlet on its longitudinal axis. The bulk permeability of the rubble pile progressively increases from the center to the wall of the reactor. The rubble pile is created by undercutting a carbonaceous deposit and expanding, as by explosives, the unexcavated deposit overlying the undercut.

Rothman, A.J. and A.E. Lewis. Experimental Work on Oil Shale at Lawrence Livermore Laboratory and Predictions of Retorting Characteristics of Oil Shale. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 21 Jun 1977.

An experimental program is being carried out to advance oil-shale retorting technology. This paper summarizes some results of laboratory and pilot retorting and gives the reactions of oil-shale char with gases. A computer model of the retorting process has been compared with retort experiments and has been used to predict in situ retorts under various operating conditions. Finally, the results of a retort using Negev (Israel) oil shale are compared with those using Colorado oil shale.

Rothman, A.J. Promises and Problems in In Situ Oil Shale Development. (Univ. of California, Livermore). pp. 159-168 of In Resource Recovery. Albuquerque, NM; American Society of Mechanical Engineers (1975).

A process is described for obtaining oil from oil shale by mining, creating a rubble column underground, and retorting in place. This rubble in situ extraction process (RISE) is compared with other potential methods for extraction of oil from oil shale, and appears

to have advantages in producing oil at lower cost, capital investment, environmental impact, water use and population influx. As such, the process, if successfully developed on a commercial scale, can have significant impact in increasing our oil supply. Various technical and other problems to be resolved in a development program are given.

Schora, F.C. Jr., H.L. Feldkirchner, P.B. Tarman, and S.A. Weil. Conversion of Oil Shale by Controlled Hydrogasification. (Institute of Gas Tech., Chicago). pp. 11. Session IV, Paper 2 of In Proceedings of the third conference on natural gas research and technology. White, J.W. (ed.). Chicago, IL; Institute of Gas Technology (1974).

A new process has been developed for converting oil shale to pipeline gas by direct hydrogasification. This process uses countercurrent shale/hydrogen contacting and excess hydrogen. Laboratory- and benchscale tests have demonstrated that as much as 95 percent of the organic matter in the shale can be converted to useful products. Along with the results obtained thus far, the design of a 1 ton per hour process development unit is discussed as well as commercial process concepts.

Schora, F.C. Hearing on Conversion of Oil Shale To Synthetic Fuels, October 7-9, 1975. (Institute of Gas Technology, Chicago, Ill. (USA)). Sep 1975. p. 27.

The principal process steps of the IGT process as applied to above-ground oil shale hydroretorting are discussed and illustrated. Raw, crushed shale passes downward as a moving bed through a reactor that is internally divided into three continuous-operation zones. The feed shale is prehydrogenated and preheated in the upper zone, and hydroretorted and/or hydrogasified in the middle zone. The spent shale is cooled in the bottom zone. Hydrogen feed to the bottom zone recovers essentially all the sensible heat in the spent shale, then uses this heat to preheat the feed shale in the upper zone. This hydrogen stream bypasses the middle zone, where the major portion of retorting occurs. In the manner described, highly efficient, countercurrent heat utilization can be obtained in the upper and lower zones without the usual problems of condensation of retorted oils and resultant plugging of the shale preheat bed. A separate hydrogen stream passes through the middle zone and hydroretorts the prehydrogenated kerogen to produce a mixture of gaseous and vaporized hydrocarbons. The effluent gases and vapors from the middle zone are cooled; the resulting oils are collected and fractionated. The heavy fraction is used for hydrogen production; the high-quality, low-sulfur fraction is one of the coproducts. The effluent gases are further processed into pipeline quality gas. If desired, any suitable portion of the light fraction can be readily hydrogasified and upgraded to produce additional quantities of high-Btu pipeline gas. Tests with a simulated in situ retort on the applicability of the method to the underground processing of oil shale were encouraging. Flow sheets for above-ground and in situ versions of the process are included.

Schora, F.C. Progress on the A.G.A.-Supported Research on Coal Gasification. (Institute of Gas Technology, Chicago, Ill. (USA)). 1975. p. 25.

Projects discussed in this report include: methanation catalyst development; high-pressure elevated temperature CO₂ scrubbing of coal gas; controlled explosive gasification; hydrogasification of oil shale; solids fluidization relating to coal gasification; acid-gas and trace impurity removal; modeling of coal gasification fluidized-bed reactors for scale-up and commercial design; ultra-filtration for coal gasification processes; kinetics of devolatilization and rapid-rate methane formation; relation of coal properties to gasification reactivity; evaluation of shift catalysts; and a survey of R and D projects directed toward conversion of coal to gaseous and liquid fuels.

Schulman, B.L. Shale Matrix Plays Important Role in Energy from Oil Shale. (Oil Shale Corp., Golden, CO). AIChE Symp. Ser.; 72: No. 155, 39-43(1976).

Processing oil shale to make raw shale oil or gaseous products can be effectively aided by appropriate uses of the chemical and catalytic properties of the shale matrix (spent shale). The sulfur content of gas streams can be controlled and the steam-carbon reaction catalyzed under gasification conditions.

Sisemore, C.J. Method for Maximizing Shale Oil Recovery From an Underground Formation. (to Dept. of Energy). US Patent Application 838,274. 30 Sep 1977. p. 9.

A method is described for maximizing shale oil recovery from an underground oil shale formation which has previously been processed by in situ retorting such that there is provided in the formation a column of substantially intact oil shale intervening between adjacent spent retorts. The method includes the steps of backfilling the spent retorts with an aqueous slurry of spent shale. The slurry is permitted to harden into a cement-like substance which stabilizes the spent retorts. Shale oil is then recovered from the intervening column of intact oil shale by retorting the column in situ, the stabilized spent retorts providing support for the newly developed retorts.

Smith, J.W., T.N. Beard, and L.G. Trudell. Colorado's Primary Oil-Shale Resource for Vertical Modified In Situ Processes. (Department of Energy, Laramie, Wyo. (USA). Laramie Energy Research Center). Apr 1978. p. 74.

Vertical modified in situ processes for oil-shale development require an accessible, thick and continuous oil-shale section. In Colorado's Piceance Creek Basin the Mahogany zone and its overlying oil-shale is the Green River Formation section that best meets these requirements. This oil-shale section is described and evaluated in detail with contour maps of richness, thickness, and oil resource in place. Seven cross sections were constructed to provide the framework necessary for basin-wide correlation of assay

results from 189 cores. These correlations form the basis for detailed contouring and resource evaluation of the Mahogany zone, A-groove, and 5 overlying oil-shale sections. Total oil in place basin-wide in this primary resource is 419 billion barrels (61 billion tonne) with 85% occurring in areas with resource exceeding 400,000 bbls per acre (143,000 tonne/hectare). 95% of the resource occurs where average richness of the total section exceeds 14 gallons per ton (58 liter/tonne). Thickness of the continuous section reaches 600 feet (183 meters) and virtually all the resource occurs in sections thicker than 300 feet (91 meters). 24 figs.

Stevens, A.L. (ed.). Oil Shale Programs Second Quarterly Report, April 1976-June 1976. (Sandia Labs., Albuquerque, N.Mex (USA)). Sep 1976.

Characterization tests performed at Green River Site 2 and fracture calibration tests performed at Rock Springs Site 6A are summarized. These field studies are part of diagnostic and rock mechanics support for in situ oil shale research. Progress is also reported on studies on advanced instrumentation techniques for in situ oil shale processing. These include development of a solid electrolyte oxygen sensor and an acoustic technique for characterizing oil shale particle size distribution in the fragmented zone following explosive fracturing of a deposit. Preliminary studies on the fracture toughness of oil shale are reported. Separate abstracts were prepared for Appendices A, B, and C.

Stevens, A.L. (ed.). Oil Shale Programs Third Quarterly Report, July 1976-September 1976. (Sandia Labs., Albuquerque, N.Mex. (USA)). Jan 1977.

Diagnostics and rock mechanics support studies for the Laramie Energy Research Center (LERC) in situ oil shale program are reported under the following headings: general design of field experiments, site 6A fielding activities, and site 12 fielding activities. Advanced instrumentation studies for in-situ oil shale processing include oxygen probe development; and particle size distribution-acoustic technique. In situ oil shale bed preparation studies include quasi-static testing of oil shale, fracture mechanics of oil shale, and computer simulation of a bore hole explosive detonation.

Stevens, A.L. (ed.). Oil Shale Programs. Fourth Quarterly Report, October 1976-December 1976. (Sandia Labs., Albuquerque, N.Mex. (USA)). Feb 1977.

Three programs funded by the Oil, Gas and Shale Technology Division of US ERDA are reported: (1) Diagnostics and Rock Mechanics Support for the Laramie Energy Research Center (LERC) In Situ Oil Shale Program, (2) Advanced instrumentation and field projects for in situ oil shale processing, and (3) In situ oil shale bed preparation study. Each of these programs is treated individually. Scope and plans necessary to meet the objectives are briefly stated. Activities on each program over the past quarter are discussed.

Stone, R.B. and J.L. Ash. Technical and Economic Study of an Underground Mining, Rubblization, and In Situ Retorting System for Deep Oil Shale Deposits. Phase I Report. (Fenix and Scission, Inc., Tulsa, Okla. (USA)). Aug 1975. p. 231.

This report contains the Phase I results of a technical and economic evaluation of conceptual systems for the underground mining, rubblization, and in situ retorting of deep oil shale deposits. Study efforts were first directed towards evaluation of the applicable geology, associated minerals, rock mechanics, in situ retorting, access mining, ventilation, rubblization, safety and environmental impact factors. Conceptual systems were synthesized and then evaluated against these factors from both a technical and economic viewpoint.

Stout, N., G. Koskinas, and S. Santor. Laboratory Apparatus for Controlled Time/temperature Retorting of Oil Shale. (Univ. of California, Livermore). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 22, No. 3, 75-84(1977).

The Lawrence Livermore Laboratory designed, built, and tested a simplified laboratory retort system (KSS apparatus) that simulates conditions involved in in situ oil shale processing. The apparatus is of simple design, and it can be used with commercially available cylindrical furnaces. The welded closure is rugged and leak-tight. When operated in the Fischer assay mode, the apparatus gives results indistinguishable from those of a Fischer assay. The KSS apparatus is versatile. It can provide excellent mass balance in a wide variety of retorting experiments. Various sweep gases can be used. The heating schedule is completely programmable, and the apparatus can run unattended for long periods (greater than 1 month).

Trabandt, C.A. Oil Shale: Acceleration of its Development. Technical Report. (Midland Coal Co., Trivoli, Ill. (USA)). 9 Oct 1974.

Development Engineering, Inc. (DEI), a wholly owned subsidiary of the Paraho Development Corporation, has submitted a proposal to the Office of Naval Petroleum and Oil Shale Reserves of the Department of the Navy for the acceleration of oil shale development. The proposal was prepared after a series of meetings and discussions with various representatives of the Department of Interior and the Department of the Navy who are associated with oil shale development and/or the Naval Oil Shale Reserves (NOSR). The general thrust of the proposal is the expansion and extension of an existing oil shale research project utilizing the Paraho oil shale retort process. The project is being conducted under a lease arrangement with the Department of the Interior which includes the use of oil shale from the NOSR. This evaluation will discuss the DEI proposal in terms of the justification, the feasibility, required implementation action, and several special considerations for the Department of the Navy. The discussion is based on the substance of DEI's proposal and independent investigations in several areas associated with the proposed effort.

Tyner, C.E. Compressor Costs for True In Situ Oil Shale Retorting.
(Sandia Labs., Albuquerque, N.Mex. (USA)). Mar 1978.

Equipment and operating costs for the compressor facilities required for true in situ oil shale retorting are expected to be less than \$2.50 per barrel of oil produced for formations with permeabilities of 10 darcys or more. These costs can be expected to rise, however, to between \$10 and \$17 per barrel for formations with permeabilities around 10 millidarcys. This dollar range is based on fifty percent resource recovery, 5 cents/kwh electric power, and the flow of air only (no liquid products) through the shale bed. Changes in these conditions (or others assumed in the calculations) will generally increase these costs.

Weil, S.A., H.L. Feldkirchner, and P.B. Tarman. Hydrogasification of Oil Shale. (Inst. of Gas Tech., Chicago). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 19: No. 2, 123-146(1974).

An improved process for production of pipeline gas and oil by direct hydrogasification of oil shale has been developed. The process uses controlled countercurrent shale heating in the presence of hydrogen. This approach results in high organic carbon recovery. Also, because of the countercurrent operation, better heat recovery should be possible in commercial operation resulting in higher overall process efficiency. Tests conducted in a laboratory thermobalance on Colorado oil shale have demonstrated the feasibility of recovery over 95 percent of the organic carbon initially present. It was concluded that prehydrogenation at 700 to 1000°F followed by heating in hydrogen above 1000°F favors maximum organic carbon recovery. Results obtained in a 4-inch-diameter reactor in continuous operation generally verified the high yields observed in the thermobalance studies. Organic carbon recoveries as high as 95 percent at pressures as low as 250 psig were achieved in this equipment. These results showed that operating conditions could be adjusted to produce primarily gaseous or primarily liquid products. Up to 65 percent of the organic carbon was gasified in soem tests and up to 80 percent of the organic carbon was converted to oil in others.

Willis, R.H. Substitute Natural Gas: Routes and Recent Developments.
Gas Eng. Manage.; 16: No. 6, 211-219(Jun 1976).

A current status survey of gas production from solid and liquid fossil fuels covers basic principles of SNG production; process routes for SNG from coal; processes currently operational or ready for commercial operation (Lurgi, Koppers-Totzek, Winkler); processes under development and proposed (British Gas/Lurgi slagging gasifier, Hygas, CO₂ acceptor, BI-GAS, Synthane, and COGAS); SNG from oil shale; and SNG from biomass.

Wise, R.L., H.G. Harris, and H.C. Carpenter. Proposed Development Plan for a Modified Horizontal In Situ Experiment. (Laramie Energy Research Center, WY). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 21: No. 6, 123-136(1976).

A research program for the development of an in situ technology for the recovery of oil shale from beds of thin strata is described. The program has been designed for five consecutive phases extending over a total of five years. Two possible field site locations in the White Mountain region of western Wyoming, near Rock Springs, have been selected. A corehole program as well as environmental studies have been initiated on these proposed sites. A mining plan has been designed to provide for determining blasting techniques, theoretical design data relating to heat effects on mine pillars, retort configuration and a general mining plan to minimize environmental impact. A retorting plan has also been developed to test both direct and indirect heating modes, as well as both vertical and horizontal retorting techniques.

Wise, R.L., B.C. Suddath, J.M. Winter, L.P. Jackson, and A. Long. Preliminary Evaluation of Rock Springs Site 9 In Situ Oil Shale Retorting Experiment. New York; American Institute of Mining, Metallurgical, and Petroleum Engineers (1976). p. 12.

Successful startup of an in situ retorting experiment in the Tipton Member of the Green River oil shale formation near Rock Springs, Wy., began on April 5, 1976, at Rock Springs site 9. The target shale was located in a 40-ft zone between 137 and 177 feet beneath the surface and averaged 21.3 gallons of oil per ton and 2.3 percent water by Fischer assay. The oil shale was retorted in advance of the combustion front which propagated radially toward eight surrounding production wells. About 700 gallons of oil and 165 MM Btu of low-Btu gas were recovered during the first 35 1/2 days of operation. Preliminary evaluation indicates that only a fraction of the oil shale reserves were retorted in advance of the combustion front. Post-retorting core samples will be evaluated after the experiment is finished. At the time this paper was prepared, the experiment was still continuing and data from only the first 35 1/2 days of operation were available. When the experiment is completed, data from environmental monitoring of the experiment will also be evaluated to determine the impact of in situ oil shale processing on air, water, and land quality.

General Information

Oil Shale and Tar Sand Research. Jun 1977.

In Pacific Northwest Laboratory annual report for 1976 to the ERDA Assistant Administrator for Environment and Safety. Part IV. Physical and technological programs.

During the development of new energy technologies, concern has arisen as to their potential effects on human health and the environment. In order to identify these potential effects early in process development, it is necessary to chemically and physically characterize the effluents from various pilot operations. Because of the complex nature of the samples, new sampling and analytical techniques need to be developed. In this section new or improved techniques for both organic and inorganic analysis are described along with applications to effluents from coal conversion, oil shale retorting and geothermal pilot operations. Also described is a program for providing relatively homogeneous and well-characterized research materials from oil shale and coal conversion pilot plants for biological and environmental studies and interlaboratory comparison.

Synthetic Fuels: Oil Shale, Coal, Oil Sands. Syn. Fuels; 15: No. 1, 1-208(Mar 1978).

The current status of synthetic fuel projects based on oil shales, oil sands and coal are reviewed and their present status given. Articles are listed under various headings, such as government, corporations, environment, technology, land, water, etc. Recent publications in these areas are listed.

Laramie, Wyoming. Bibliography of Publications Dealing With Oil Shale and Shale Oil From U.S. of Bureau of Mines, 1917-1974, and the ERDA Laramie Energy Research Center, 1975- (Energy Research and Development Administration, Laramie, Wyo. (USA). Laramie Energy Research Center). Sep 1977. p. 53.

BOM began investigation of shale-oil production during World War I. This research continued at a low level until the Synthetic Liquid Fuels Act in 1944 set up two major research installations at Rifle, Colorado, and at the Laramie experiment station in Wyoming. After 1956, the demonstration plant at Rifle was closed and the Laramie station (LERC) became the sole site of federal research, particularly after the Arab oil embargo. This bibliography of approximately 750 citations is arranged according to year.

_____. Salt Lake City, Utah. Energy Resources Map of Utah. Salt Lake City; Utah. Geological and Mineral Survey (1975).

The in-depth color-coded map of Utah issued by the Utah Geological and Mineral Survey, Department of Natural Resources State of Utah shows the geology of the state. Then superimposed are shown areas of oil and gas pipelines, fields, processing plants, and ages of formations; oil-impregnated rock deposits; oil shale deposit locations; veins of gilsonite; coal deposit and operating coal mine locations; uranium mining districts; geothermal fields, and major transmission electric power lines and power plants.

_____. Washington, D.C. Fossil Energy Research Program of the Energy Research and Development Administration, FY 1977. (Energy Research and Development Administration, Washington, D.C. (USA)). Apr 1976. p. 276.

The Fossil Energy Research, Development and Demonstration programs of the Energy Research and Development Administration are being expanded in response to the national need to develop adequate amounts of clean fossil fuel from domestic resources. The need for these programs and their relationship to other energy research efforts were contained in ERDA-48, A National Plan for Energy Research, Development and Demonstration, released in the summer of 1975. The update of the National Energy Plan (ERDA-76-1) is now available. Additional details are provided here on the projects underway and planned in Fossil Energy, with specific emphasis on the President's FY 77 Budget Request. The research planned and documented is guided by the following overall program goals: (1) to develop the technology needed to make fossil fuels available in the form and quantity needed, and (2) to assure that the nation's fossil fuels resources are developed at acceptable economic, social, and environmental costs. Funding requirements for the programs discussed are based on the attainment of these major goals.

_____. Arlington, Virginia. Meeting Report: Advanced Fossil Fuels Sector Group, Las Vegas, 25 August 1976. (Stanford Research Inst., Arlington, Va. (USA)). Oct 1976.

The general areas of concern were: Advanced oil processing; Chemical coal cleaning; Synthetic fuels environmental assessment; Synthetic fuels control technology development; High temperature/high pressure particulate treatment; Environmental processes and effects.

_____. Golden, Colorado, Research on Petroleum, Natural Gas, and Oil Shale: the University's Role. (Colorado School of Mines, Golden (USA)). Apr 1976. p. 79.

Objectives of this workshop were to identify possible areas of constructive research in petroleum, natural gas, and oil shale development, production, and utilization that can be carried out best in universities. Eight papers and several discussions are included. Separate abstracts were prepared for four pages.

Acheson, W.P., H.H.A. Huygen, and R.P. Trump. Shale Oil Recovery Process. (to Gulf Research and Development Co.). US Patent 4,015,664. 5 Apr 1977.

A method for recovering shale oil and gas from subsurface oil shale deposits is described in which free space is formed in the shale deposit and relieved blasting toward the free space from first shot space with rubble. In situ combustion of the rubblized shale decomposes organic material in the shale to form shale oil and gas, which are conveyed by combustion products through the shot holes to the surface, and leave a weak, easily compressible spent shale. After the in situ combustion, shale surrounding the spent shale is rubblized by explosives detonated in second shot holes blasting toward the previously retorted zone. The second shot holes, which also are drilled from the surface into the shale, are spaced laterally from the first shot holes. The rubblized shale is then retorted by in situ combustion. The successive rubblizing and in situ combustion steps can be repeated to move the combustion operation laterally through the shale deposit. 9 claims, 5 figures.

Ban, T.E. Process for Retorting Oil Shale. (to McDowell-Wellman Engineering Co.). US Patent 4,039,427. 2 Aug 1977.

A process is given for the recovery of oil from oil-bearing shale and for employing the oil-depleted shale as a combustible heat source. The oil-bearing shale is charged on a traveling grate to form a burden. A bed of oil-depleted shale having uncombusted carbon and hydrocarbons is provided, and those uncombusted materials are combusted to raise the temperature of the bed to above about 1000°F. A reducing atmosphere is passed through the oil-depleted and combusted bed to raise the temperature of the reducing atmosphere. The heated reducing atmosphere is then passed through the burden to raise the temperature of the oil shale to at least 800°F and to thereby educt oil from the oil shale. In another embodiment, the combusted oil-depleted material is layered onto the oil-bearing and the reducing atmosphere is passed sequentially through the oil-depleted and oil-bearing material.

Bartke, T.C. and J.J. Duvall. Effects of Particle Size on Retorting Oil Shale in a Controlled-state Retort. (Energy Research and Development Administration, Laramie, WY). 1977.

Experiments were conducted in a controlled-state retort at the Laramie Energy Research Center to determine the effect of oil shale particle size on the boiling range distribution of shale oil and unretorted bitumen. This study also provided insight about the movement of shale oil over unretorted oil shale. Oil shale, in the particle size ranges 3/64- to 3/8-inches, 1/8- to 1/2-inches, and 3/8- to 3/4-inches, was retorted in interrupted and completed experiments. All experiments were conducted with nitrogen as the carrier gas to avoid combustion. Data included the amounts of shale oil and unretorted bitumen recovered, boiling range distri-

bution of the shale oils and bitumens, analyses of the shales, and effluent gas compositions. Analysis of the data showed that the smallest oil shale particles (1) retained more shale oil on their surface, (2) allowed shale oil to emerge from the oil shale at a lower temperature, (3) yielded a lower boiling crude shale oil, and (4) retained more carbon residue on the retorted shale.

Branch, M.C. and R.A. Ness. Combustion Front Propagation Through Fractured Oil Shale. (Univ. of California, Berkeley). pp. 20 Paper 10 of In Combustion of coal, oil shale, and tar sands. Combustion problems related to the enhancement of energy efficiency. Tustin, CA; Combustion Inst. (1976).

The in situ recovery of oil from oil shale requires fracturing oil shale underground to establish permeability and passing air through the fractured shale to support a combustion front. The heated products from the flame front contact the untreated shale where kerogen is decomposed and gas and liquid products are swept to a production well. A major difficulty in this technique is control of the combustion front. An experimental study of flame front propagation through crushed oil shale in a laboratory reactor is presented. The oil shale is ignited at the top of a vertical two-inch insulated stainless steel tube and the reaction maintained by air injection above the ignition plane. The structure of the reaction front and flame front propagation rates are studied as a function of oil-shale particle size and air delivery rates. Temperature profiles throughout the reaction front were measured continuously by coated thermocouple probes and oil yield determined for each run. Combustion front advance was found to reach steady state very rapidly and a linear relationship was found between steady flame front propagation rate and air flux and between particle size and flame propagation rate. The reaction temperature is about 2100°F and is slightly dependent on particle size and air flux. In contrast to sand pack studies the flame front was quite narrow without substantial preheating of downstream shale.

Campbell, J.H. and J.R. Taylor. Effects of Steam on Oil Shale Retorting: a Preliminary Laboratory Study. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 10 Apr 1978.

This preliminary study reports the effects of flowing steam (1-atm total pressure) on the pyrolysis of shale and subsequent decomposition of mineral carbonates. Results show that steam enhances oil yield during pyrolysis. However, this effect depends strongly on the size of the shale particles and produces significant yield enhancement only for small particles (powdered shale 800 m). No dramatic change in the properties of the product oil resulted from retorting in steam. We also measured the rate of mineral carbonate decomposition and found it to be accelerated in the presence of steam. For example, the dolomite decomposition rate increased threefold in the presence of 100% steam (1 atm).

Gregoli, A.A. Fluidized Bed Hydroretorting of Oil Shale (to Cities Service Co.). US Patent 4,075,081. 21 Feb 1978.

Oil shale, crushed to about 70 mesh size (300 microns or less), is slurried with a recycle stream from the processing of the reactor effluent. The slurry is then heated and charged, along with hydrogen, to an upflow, fluidized bed reactor. The kerogen in the shale undergoes hydroretorting, giving a C₁-650°F range of products. The spent shale is removed with and separated from the reactor overhead effluent.

Hanson, L. Apparatus and System for Processing Oil Shale. US Patent 4,065,361. 27 Dec 1977.

Apparatus is described for treating oil shale by microwave energy for recovering heated volatile fractions thereof. The microwave oven includes a sloping feeder made of glass, pyrex, or ceramic material, which feeder is reciprocated back and forth along a declining plane so as to advance slowly but progressively oil shale deposited on the top end thereof to the discharge end of the vibrator. Means are provided to evacuate volatile fractions and to feed such gases through preheater tubes to a condenser unit. The preheater tubes are disposed in line with and through the flow of incoming materials so as to tend to regulate material descent as well as preheat the shale. An additional solids heat exchanger is employed underneath the discharge end of the vibratory feeder means so as to slow the descent of the spent shale onto its ultimate conveyor as well as taking heat therefrom and from the magnetron tubes of the oxygen to conduct such heat upwardly to further increase the preheating effect upon incoming shale. Condenser units are employed and a prime mover-generator unit are used to utilize a portion of the recovery for ultimately powering such magnetron tubes to produce the electro-magnetic wave energy necessary to heat the shale and vaporize its bituminous constituents.

Hill, R.F. ESCOE Engineering Program. Quarterly Report, March 1, 1977-May 31, 1977. (Engineering Societies Commission on Energy, Inc., Washington, D.C. (USA)). Aug 1977.

The objectives of this program are to conduct independent studies and to provide technical assistance to the Fossil Energy Office of Program Planning and Analysis. To achieve this objective ESCOE will utilize a team of experienced engineers and scientists who come from the academic, industrial, and technical communities and who have significant experience in energy development and utilization. These principal research personnel will be assigned for a temporary period of about two years and will be replaced by similarly qualified people to insure that current technical information and knowledge is available to ERDA. Work assignments will be performed pursuant to tasks developed by the technical representative from ERDA with the assistance of the Program Manager from ESCOE. Each work assignment will be specific as to the work to be performed and the date of completion.

Hundemann, A.S. Oil Shale Mining, Processing, Uses, and Environmental Impacts (citations from the NTIS Data Base). Report for 1974-Mar 1976. (National Technical Information Service, Springfield, Va. (USA)). May 1976. p. 228.

Exploration, mining, retorting, chemistry, environmental impacts, and policies relating to oil shale research are covered. Abstracts discuss such things as oil shale air and water pollution control, production of synthetic fuels, use of spent oil shale in road construction, identification of research and development priorities, and in situ recovery of shale oil. (This updated bibliography contains 223 abstracts, 87 of which are new entries to the previous edition.)

Hundemann, A.S. Oil Shale Mining, Processing, Uses, and Environmental Impacts. Volume 1. 1964-1975 (citations from the NTIS Data Base). Report for 1964-1975. (National Technical Information Service, Springfield, Va. (USA)). May 1977. p. 200.

Government-funded research on exploration, mining, retorting, chemistry, environmental impacts, and policies relating to oil shale research is covered. Abstracts discuss such things as oil shale air and water pollution control, production of synthetic fuels, use of spent oil shale in road construction, identification of research and development priorities, and in situ recovery of shale oil. (This updated bibliography contains 195 abstracts, none of which are new entries to the previous edition.)

Hundemann, A.S. Oil Shale Mining, Processing, Uses, and Environmental Impacts. Volume 1. 1970-1975 (citations from the Engineering Index Data Base). Report for 1970-1975. (National Technical Information Service, Springfield, Va. (USA)). May 1977. p. 219.

Exploration, mining, retorting, chemistry, thermal studies, environmental impacts, and policies relating to oil shale research are discussed. A few abstracts deal with the production of synthetic fuels from shale oil and the economics of oil shale operations. (This updated bibliography contains 212 abstracts, none of which are new entries to the previous edition.)

Hundemann, A.S. Oil Shale Mining, Processing, Uses, and Environmental Impacts. Volume 1. 1976-April, 1977 (citations from the Engineering Index Data Base). Report for 1976-Apr 77. (National Technical Information Service, Springfield, Va. (USA)). May 1977. p. 138.

Worldwide research on exploration, mining, retorting, chemistry, thermal studies, environmental impacts, and policies relating to oil shale research is discussed. A few abstracts deal with the production of synthetic fuels from shale oil and the economics of oil shale operations. (This updated bibliography contains 131 abstracts, 112 of which are new entries to the previous edition.) See also NTIS/PS-77/0386, Oil Shale Mining, Processing, Uses, and Environmental Impacts. Vol. 1. 1970-1975.

Hundemann, A.S. Oil Shale Mining, Processing, Uses, and Environmental Impacts. (citations from the Engineering Index Data Base). Report for 1970-Mar 1976. (National Technical Information Service, Springfield, Va. (USA)). May 1976. p. 236.

Exploration, mining, retorting, chemistry, thermal studies, environmental impacts, and policies relating to oil shale research are discussed. A few abstracts deal with the production of synthetic fuels from shale oil and the economics of oil shale operations. (Contains 231 abstracts).

Johnson, R.C. Preliminary Geologic Map, Oil Shale Yield Histograms, and Stratigraphic Sections, Long Point Quadrangle, Garfield County, Colorado. Washington, D.C.; Geological Survey (1975).

Rich oil shale crops out near the tops of the three mesas in Long Point quadrangle. Rich oil shale is mainly confined to the Mahogany zone and above. Lower oil shale zones defined by Cashion and Donnell (1972) are poorly developed in this quadrangle. In general oil shale becomes thicker and richer to the northeast. Some rough estimates of potential oil shale resources have been made by C.W. Keighin (oral commun., 1975). In sequences greater than 10 feet (3m) thick and assaying 30 gallons of oil per ton, Cow Ridge has 30 million barrels, Kimball Mountain has 15 million barrels, and the mesa in the northeast part of the quadrangle 270 million barrels of oil in place. In sequences greater than 10 feet (3m) thick and averaging 45 gallons of oil per ton, Kimball Mountain contains 8 million barrels and the mesa in the northeast part of the quadrangle, 95 million barrels of oil; Cow Ridge contains no oil shale of this grade.

Knudsen, C.W. Coal and Oil Shale Utilization. (Energy Research and Development Administration, Washington, D.C.). p. 245-248 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers (1976).

Government-supported research on coal liquefaction, gasification, direct combustion, and magnetohydrodynamics is reviewed. In the development of oil shale as an energy source, government effort is concentrated on in situ methods. These programs are discussed briefly.

Kreinin, E.V. and K.N. Zvyagintsev. Method of Connection of Wells by In Situ Combustion. US Patent 4,036,298. 19 Jul 1977.

A method of mine-less connection of wells for underground gasification by the filtrational fire connecting techniques is intended primarily for forming a single unitary gasification channel for underground gasification of coal, oil shale and oil-bearing beds. In the disclosed method of connecting wells or boreholes drilled for underground gasification, the coal bed is ignited in one of the

wells situated in the direction of formation of the unitary gasification channel. After a center of combustion has been set in this well, an air blast is directed at a permanent flow rate into the well with which the connection is to be effected. The pressure of the air blast charged into the well is measured, and when the pressure drops considerably, an air blast is charged for connection purposes into the next successive well in the direction of formation of the gasification channel. The disclosed method provides for maintaining the combustion source in the area of the well connected with the gasification channel and thus for ensuring reliable formation of the unitary single gasification channel. 3 claims, 5 figures.

Lee, H., T.O. Peyton, R.V. Steele, and R.K. White. Potential Radioactive Pollutants Resulting from Expanded Energy Programs. Final Report. (Stanford Research Inst., Menlo Park, Calif. (USA). Center for Resource and Environmental Systems Studies). Aug 1977.

An effective environmental monitoring program must have a quality assurance component to assure the production of valid data. Quality assurance has many components: calibration standards, standard reference materials, standard reference methods, interlaboratory comparison studies, and data validation. The purpose of this document is to identify and document the potential radioactive pollutants that could result from the expanded energy program and for which quality assurance programs must be provided. The radio-nuclide releases and the resulting population exposure doses from several energy systems for four projected energy utilization scenarios were calculated and compared. The energy system components examined were: coal mining, processing, combustion, and ash disposal; coal gasification and liquefaction; oil shale mining, processing, residue disposal and product utilization; geothermal and development and operations; uranium mining, milling, conversion, enrichment and fabrication; nuclear reactor operations; and fuel reprocessing and waste disposal.

Le Goff, Y. Shale Tomorrow. I. The World Situation. Pet. Inf.; No. 1398, 12-15 34(Jun 1976).

A survey covers the difficulty of determining profitability, the change in the economic situation since the 1973 oil crisis, oil shale development in the world in 1838 to 1950, U.S. experience, including the Union Oil Corp. of California and Shale Oil Corp retorting processes and the U.S. Bureau of Mines and Garrett Research and Development Co. Inc. in situ processes, and developments in Brazil, including an imminent decision on the construction of a 50,000 to 100,000 bbl/day retorting plant.

. Murray, D.K. (comp.). Energy Resource Development Map of Colorado.
Denver; Colorado Geological Survey (1976).

The Colorado Geological Survey prepared Map Series 6 entitled "Energy Resource Development Map of Colorado," compiled by D. Keith Murray. This two-color map is published at a scale of 1: 500,000 (one inch equals approximately 8 miles) and measures 42" x 58". This map displays all of the known energy-related projects and conversion facilities proposed or planned in Colorado as of January 1, 1976, together with the locations of the State's energy resources. The projects shown on the map include Federal Known and Proposed Coal Leasing Areas and Known Geothermal Resource Areas, uranium prospecting permit areas, existing and proposed power generating plants, active and proposed surface and underground coal mines, sites of oil shale activity, 1975 oil and gas discoveries, and locations of uranium/vanadium mills. The energy resources portrayed on the map include the approximate extent of the coal-bearing regions; distribution of surface or near-surface coal-bearing strata, including that which may be potentially "strip-pable" (shown as a green overprint); distribution of oil shale; oil and gas fields; uranium resource areas; and thermal springs and wells. This useful exploration, development, and planning tool was prepared in cooperation with the Governor's Energy Policy Council and the Colorado Energy Research Institute.

Needham, R.B. Prediction of the Permeability of a Fragmented Oil Shale Bed During In Situ Retorting with Hot Gas. Dallas; American Inst. of Mining, Metallurgical, and Petroleum Engineers (1976). p. 8.

The operability of in situ oil-shale retorting has been established by retorting beds of crushed shale under lithostatic loads simulating the column loads to be encountered in practical operations. The resulting compaction and reduction in permeability were correlated to predict the final permeability behavior of an actual fragmented in situ bed with particles averaging 6 in. in diameter. Two compaction cells, 1.25 and 5 in. in diameter, were used for the retorting experiments in which the permeability of the compacted bed was determined for average shale particle size from 0.046 to 1.0 in., shale richness from 18 to 58 gal/ton, lithostatic load from 70 to 900 psi and heating rate from 5 to 100°F per hour. A correlation was developed that predicts the permeability using the lithostatic pressure, shale richness, and particle size for a shale heating rate of 10°F per hour. The modified Kozeny equation was used as the theoretical basis for the correlation and the measured permeabilities could be predicted with an average error of 21 percent.

Nielsen, J.M. Pacific Northwest Laboratory Annual Report for 1977 to the DOE Assistant Secretary for Environment. Part 4. Physical Sciences. (Battelle Pacific Northwest Labs., Richland Wash. (USA)). Feb 1978.

Research programs in the areas of coal, dosimetry, geothermal, and oil shale are briefly indicated. Analytical chemistry support is also summarized. Abstracts were prepared for each of these areas.

Prast, W.G. U.S. Bureau of Mines Mining Research Programs. Min. Mag.; 137: No. 2, 115-117, 119, 121(Aug 1977).

The U.S. Bureau of Mines is carrying out a number of mining research programs, the objectives of which are in general to increase efficiency, safety and productivity in U.S. mines--particularly coal mines. In this article details of the various programs currently under way are given, covering almost all aspects of coal mining and including surface mining, oil shale mining and metal/non-metal mining. 7 ref.

Prien, C.H. Survey of Oil-shale Research in the Last Three Decades pp. 235-267 of In Oil Shale. Yen, T.F., G.V. Chilingarian, (eds.). New York; Elsevier Scientific Publishing Co. (1976).

In the past twenty years, six world oil-shale industries, i.e., those in Scotland, Sweden, Spain, France, Australia, and South Africa, have ceased to operate. Only the shale industry of the U.S.S.R., with an annual capacity of 26 million tons of shale, and that of the People's Republic of China, with a throughput of somewhere between 35 and 50 million tons of shale per year are still in operation. The Soviet industry is facing increasing competition from natural gas and is, therefore, turning increasingly to the production of chemical products and intermediates. Throughput continues to expand, however, with all new growth projected to be devoted almost entirely to power production. It is reasonable to expect, in the light of future energy requirements, that mainland China's shale industry capacity will also continue to rise. Increasing world energy demand and the prospect of near term energy shortages in the U.S.A. during at least the coming decade are resulting in a re-assessment of all U.S.A. energy sources, including oil shale. This is lending impetus to the development of a U.S.A. oil-shale industry, on both private and federal lands. Recent improvements in technology have reduced U.S.A. shale-oil costs to the point where they are already more than competitive with those of the new domestic petroleum. The future uncertainty of foreign import sources and the prospect of intolerably unfavorable future balance of payments is adding further incentive to developing shale oil. The embryonic Brazilian oil-shale industry is now ready to proceed through the prototype, semi-commercial stages.

Reed, F.H. Study of the Production of Shale Oil from Oil Shale in Wurtemberg. (Sandia Labs., Albuquerque, N.Mex. (USA)). May 1977.

In Appendix A the geology of the Wurtemberg oil shale deposits is described and development of oil shale processing plants during World War II in that area is reviewed. It is noted that of ten planned plants four were producing at the time of Allied Occupation. In Appendix B, experimental underground distillation of oil

shale near Schorzingen is described. Test results showed that it is possible to distill Pasidonia oil shale underground. In Appendix C, underground distillation experiments are described in which the effects of distillation chamber cross section were evaluated. In Appendix D, experiments conducted to evaluate underground oil shale distillation in very large chambers are drational data are included with each appendix.

Reed, T.G. Jr. Process for Treating Oil Shale. US Patent 3,939,057. 17 Feb 1976.

A new economical oil shale retorting process developed by T.G. Reed, Jr. is mechanically sound, produces a high yield of oil and salable high-Btu gas, is sufficiently efficient in regard to heat consumption to require little other fuel other than the char resulting from retorting, and requires a relatively small amount of water since the oil shale occurs in arid areas. The process produces a crude shale oil and a high-Btu gas by retorting crushed oil shale admixed with a small quantity of crushed coal in an indirectly heated, horizontal rotary calciner equipped with mechanical seals to contain the vapors produced and a condensing system to recover the oil vapors. Preheated (300°F) crushed shale is continuously introduced to the retort where it is further heated to 900°F and held at this temperature for about 15 min. The shale is then continuously discharged into a hopper sized to permit a residence time of about 15 min., during which time residual vapors are swept out with a small quantity of super-heated steam. The vapors from the retort and the soaking hopper are passed to a system of air-cooled condensers where the shale oil and water are condensed and separated from the gas, which is then suitable for compression and drying. The oil-free shale, containing the char produced during retorting, is fed to a furnace where it is burned to produce the heat for retorting and preheating the shale. The coal must be added to provide additional heat since the char by itself is insufficient to provide all the heat required.

Routson, R.C. and R.M. Bean. Ground Disposal of Oil Shale Wastes: A Review with an Indexed Annotated Bibliography Through 1976. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Dec 1977.

This review covers the available literature concerning ground-disposed wastes and effluents of a potential oil shale industry. Ground disposal has been proposed for essentially all of the solid and liquid wastes produced (Pfeffer, 1974). Since an oil shale industry is not actually in operation, the review is anticipatory in nature. The section, Oil Shale Technology, provides essential background for interpreting the literature on potential shale oil wastes and the topics are treated more completely in the section entitled Environmental Aspects of the Potential Disposal of Oil Shale Wastes to Ground. The first section of the annotated biblio-

graphy cites literature concerning potential oil shale wastes and the second section cites literature concerning oil shale technology. Each section contains references arranged historically by year. An index is provided.

Russell, P.L. Oil Shale Research: A Brief History. (Bureau of Mines, Denver). Q. Colo. Sch. Mines; 71: No. 4, 173-176 (Oct 1976).

A chronological listing of dates (1855 to 1976) and events that represent milestones in the development of oil shale technology is presented. It is pointed out that the U.S. Government, State of Colorado, and Colorado School of Mines have participated in the study of oil shales since 1913.

Sohns, H.W. Oil Shale: Its Role in Solving the Energy Problem. (Texas Tech Univ., Lubbock (USA)). 1973. p. 7.

The discussion is presented under the following subject headings: oil shale resource; oil shale characteristics; technology, including descriptions of gas combustion and the Union Oil Company retorts, the TOSCO II and Paraho processes and in situ retorting methods. Refining crude shale oil, environmental impact of a shale oil industry, economics of shale oil production, and the future of oil shale are also discussed.

Tham, M.J. Serially Burning and Pyrolyzing to Produce Shale Oil from a Subterranean Oil Shale. (to Shell Oil Co.). US Patent 3,987,851. 26 Oct 1976.

A process is described for producing shale oil by circulating hot fluid through a rubble-containing cavern within a subterranean oil shale which contains water-soluble mineral. The process is improved by burning a carbonaceous residue left within one cavity to produce hot fluid for operating power devices and also pyrolyzing the oil shale in a different cavity.

Todd, J.C. Gas Combustion Retort Process. (to Atlantic Richfield Co.). US Patent 3,617,466. 2 Nov 1971.

An improved method is described for obtaining oil from oil shale by the gas combustion retort process. The offgas from the retort containing oil, fuel, and other combustion products is treated first to remove the oil and second, to burn the fuel components. The resulting gas is recycled into the retort to pass counter-currently to the shale travel. Temperatures in the combustion zone of the retort are moderated and clinker formation is eliminated. The heat from the fuel burning can be used as a power source.

Utter, S. Bureau of Mines Oil Shale R and D Program. (Bureau of Mines, Denver). 1977.

Since 1974, we have been conducting an R and D program to advance oil shale mining technology. This is part of the Bureau's overall energy extraction research and development program. Our objectives are to develop, test, demonstrate and transfer to industry improved methods and equipment needed for extracting the large tonnages of oil shale and/or shale oil required for a viable synthetic liquids fuel industry. Equally large tonnage of waste shale residue from the retorting operations must be handled in an environmentally sound manner. Two major phases of the program are Baseline Studies and Development and Demonstration. Four of the Baseline Studies have been recently completed and the reports published. These describe the technical and economic feasibility of underground, open pit and modified in situ extraction methods and the physical and chemical composition of retorted shale for design of full-scale disposal plans. Several promising concepts have been developed for large-scale low-cost underground mining of the thick, deep, oil shale deposits in the central Piceance Creek Basin of Colorado. The next phase of the program is to test the validity of these concepts under actual mining conditions. Core holes have been drilled and a site selected for the testing and demonstration of these methods. Construction of a 10-ft OD bored shaft is under way. This 2,400-ft deep shaft will provide access to the lower or Saline Zone where bulk samples will be mined and geotechnical and hydrology tests conducted. This shaft may be used as a ventilation shaft for a larger experimental mining operation proposed for a later date.

Utter, S. Oil Shale R and D: A Bureau of Mines Program. (Bureau of Mines, Denver). p. 286-287 of In Proceedings of the Second annual UMR-MEC conference on energy. Morgan, J.D. (ed.). North Hollywood, CA; Western Periodicals Co. (1976).

This paper outlines the work that the Bureau of Mines is doing in oil shale mining research to enhance production goals. It describes the results of the first year's contract research program and the plans for the future. The objectives of the program are to develop, test, and demonstrate improved low-cost mining and waste management methods and equipment that are capable of producing the large tonnages of oil shale and shale oil needed by the 1980's. The immediate objectives of the program are to assess the technology and economic feasibility of various surface and underground mining methods and of modified in situ extraction systems, evaluate the mineral resources, and determine the environmental impacts of an oil shale mining industry.

Wellman, P. Oil Shale Development. (Ashland Oil, Inc., KY). p. 331-335 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers(1976).

Events leading to the present state of development of oil shale technology are reviewed. Current economic, political, environmental, and technological concerns and their impact on future development of oil shale as an energy source are discussed.

White, P.C. Fossil Energy Research Program of the Energy Research and Development Administration, FY 1978. (Energy Research and Development Administration, Washington, D.C. (USA)). Apr 1977. p. 378.

The Fossil Energy (FE) Research, Development, and Demonstration (RD and D) Programs of the Energy Research and Development Administration (ERDA) are expanding in response to the national need to develop adequate amounts of clean fossil fuel from domestic resources. The need for these programs and their relationship to other energy research efforts were contained in ERDA-48, A National Plan for Energy Research, Development, and Demonstration, released in the summer of 1975, and in ERDA-76-1, A National Plan for Energy Research, Development, and Demonstration, released in early 1976. The update of the National Energy Plan was to be available early in 1977. The purpose of this report is to provide additional details on the projects underway and planned in FE, with specific emphasis on the President's FY 1978 Budget Request. The research documented in this report is guided by the following overall program goals: to develop the technology needed to make fossil fuels available in the form and quantity needed and to assure that the Nation's fossil fuels resources are developed at acceptable economic, social, and environmental costs. These major goals have been translated into funding requirements for each of the programs.

Wilson, K.C. (ed.). Clinch River Breeder Reactor Plan Project: Chief Executive Briefing; Proceedings of the Breeder Reactor Corporation, May 1976 Information Session. (Clinch River Breeder Reactor Plant Project Office, Oak Ridge, Tenn. (USA)). 1976. p. 43.

The volume presented contains reports on the Clinch River Breeder Reactor Plant Project presented at an information session for Breeder Reactor Corporation chief executives held May 4, 1976, in Chicago, Illinois.

Yen, T.F. and G.Y. Chilingarian. (eds.). Oil Shale. New York, Elsevier Scientific Publishing Co. (1976). p. 103.

Twelve chapters are included in the book on worldwide oil shale deposits, origin of shale, mineralogy, properties of kerogen, organic components, fossil hydrocarbons, retorting, well-logging, environmental effects, and research programs. A separate abstract was prepared for each chapter.

Yen, T.F. Oil Shales of United States: A Review. (Univ. of Southern California, Los Angeles). p. 1-17 of In Science and technology of oil shale. Ann Arbor; Ann Arbor Science Publishers Inc. (1976).

The following topics are discussed: potential and distribution of oil shales; current recovery technology, including above-ground and in situ processes; and petrography of Chattanooga, Appalachian, and Green River oil shales.

Yen, T.F. (ed.). Science and Technology of Oil Shale. Ann Arbor, Ann Arbor Science Publishers Inc. (1976). p. 232.

The fifteen chapters in this book were abstracted and indexed individually for ERA/EBD.

APPENDIX D
OIL SANDS BIBLIOGRAPHY

ECONOMICS
ENVIRONMENTAL IMPACTS
PRODUCTION TECHNOLOGY
GENERAL INFORMATION

Economics

_____. Salt Lake City, Utah. Selected Research Projects Leading to the Development of Utah Coal, Tar Sands, and Oil Shale. Phase I research for the 1975-1976 period. (Utah Univ., Salt Lake City (USA)). Mar 1977.

This Phase I report is an important initial step in the long-range planning process necessary to assure the orderly and economic development of Utah's fossil-fuel resources. Basic purposes of this program are: to provide information pertinent to the development of energy resources; to improve the technology and economics of resource recovery; to identify the industrial chemical potential of resources; to explore other commercial uses of resources. To achieve these objectives, five research projects were initiated: investigation of tar sands as a potential source of asphalts and petrochemicals; solution mining of coal; feasibility of solvent extraction of bitumen from oil shale; study of the combustion process in oil shale beds; and study of the chemical values of oil shale recoverable by rapid pyrolysis. The following key conclusions were determined: asphalt from the Utah tar sands bitumen is of high quality and appears to be competitive; the unexpectedly high permeability determined for Utah coals enhances the feasibility of using the solution-mining process; Utah oil shales have been found to be high in solvent-soluble compounds, thus increasing their potential commercial value; concepts important to the rapid pyrolysis of oil shale have been demonstrated as valid; and a significant data base has been produced.

Armstrong, J. First Oil Sands Plant: A True Pioneer Project. Energy Process./Can.; 68: No. 1, 22-29(1975).

A discussion of the Great Canadian Oil Sands Ltd. project covers problems in attaining an economic operation in relation to the nature of oil sand; the four functions in producing the oil, including very large open pit mining, extraction or separation of the sand and bitumen with completely new technology, upgrading of the bitumen into synthetic oil, and onsite utilities having very large requirements; and the necessity for operating the total complex as a single plant, i.e., anything but a minor disruption of the first three functions could shut down the whole operation.

Camp, F.W. Processing Athabasca Tar Sands: Tailings Disposal. (Great Canadian Oil Sands Ltd., Edmonton, Alberta). Can. J. Chem. Eng.; 55: No. 5, 581-591(Oct 1977).

Public awareness and concern over the tailings disposal aspects of tar sand development are increasing. This paper describes why the hot water extraction process can lead to an accumulation of tailings sludge. A theory is proposed to predict tailings accumulation rate; predictions are compared with GCOS' operating experience. Using this theory, future projects can be evaluated on their merits without extrapolating GCOS's experience, which may or may not be applicable. Several unsuccessful approaches to reducing sludge accumulation are described to encourage others to seek new approaches.

Cormack, D.E., J.M. Kenchington, C.R. Phillips and P.J. Leblanc. Parameters and Mechanisms in the Solvent Extraction of Mined Athabasca Oil Sand. (Univ. of Toronto, Ont.). Can. J. Chem. Eng.; 55: No. 5, 572-580(Oct 1977).

The efficiency of solvent extraction of bitumen from mined Athabasca oil sands has been studied in laboratory-scale, batch, stirred vessels. Solvent type, solids concentration, stirrer speed and contact time have been identified as important parameters. A theoretical analysis of the extraction process provides a basis by which the various parameters are assessed in terms of relative overall mass transfer coefficients. However, because the size distribution of the oil sand aggregates is difficult to reproduce, the analysis is limited. Greater reproducibility and similar quantitative results were obtained for the dissolution of pure bitumen from the bottom of the stirred vessels. It is shown that highly aromatic solvents such as benzene and toluene can dissolve bitumen 3 to 5 times faster than an essentially aliphatic solvent such as kerosene. There is evidence, however, which indicates that solvent properties other than aromaticity are also important. The data indicate that a minimum stirrer speed must be exceeded before the extraction of oil sand or pure bitumen will proceed at a reasonable rate. Above this minimum rate, the mass transfer coefficient increases linearly with stirrer speed. The solids concentration is also important since the data suggest that a higher efficiency is obtained at higher solids concentrations in the range of solid loadings studied.

Ebanks, W.J., Jr., G.W. James and N.D. Livingston. Evaluation of Heavy-oil and Tar Sands in Bourbon, Crawford, and Cherokee Counties, Kansas. Final report. (Kansas Geological Survey, Lawrence (USA)). Dec 1977.

The current national energy-resource situation has provided the incentive to investigate more fully deposits of heavy-oil bearing sandstone in southeastern Kansas, as part of a larger, three-state study. The results of this study indicate that the size of the heavy-oil resource in the three Kansas counties studied is smaller than earlier estimates suggested. A resource of 200 to 225 million barrels of oil in-place is estimated to be present in areas of "known oil occurrence," as established by this study. The amount

of this in-place resource which may be considered to be reserves, that is, recoverable under existing technology and economics, is zero. The estimates of resource-size are severely downgraded from earlier estimates mainly because of the discontinuous nature of the potential reservoir sandstone bodies and because of the thinness and shaliness of some of these sandstones. The earlier impression of these heavy-oil reservoirs, at least in Kansas, as being widespread, heavily oil saturated, "blanket" sandstones unfortunately is not correct. There are areas, shown on maps, which may warrant further investigation because of locally good oil-saturation, i.e., more than 400 barrels per acre foot, in trends of sandstone thicker than 20 feet. It is concluded that there will be no widespread exploitation of subsurface heavy-oil sandstones within the areas of Bourbon, Crawford, and Cherokee Counties, Kansas. Smaller areas indicated here may warrant further drilling and investigation, but the potential size of the heavy-oil resource is severely downgraded from earlier estimates.

Gifford, P.H., II. Recovery of Oil From Tar Sands. (to Phillips Petroleum Co.). US Patent 4,071,434. 31 Jan 1978.

A tar sands slurry containing sand particles of varying sizes dispersed therein is passed into a classifier wherein it is subdivided into at least two streams, each stream containing either coarse or fine solids. The stream containing coarse solids is directed to a separate solids removal zone where the solids are removed. The effluent from the solids removal zone and the fine-solid-containing stream are then fed to a coking zone.

Hanson, D.O. Recovery of Oil From Tar Sands. (to Phillips Petroleum Co.). US Patent 4,071,433. 31 Jan 1978.

Tar sand is blended in a melt tank with oil to form a slurry which is separated into two streams, one containing coarse sand, the other fine sand. The stream containing fine sand is then introduced into a coker yielding coke and a hydrocarbon vapor stream; the latter is introduced into the bottom section of a fractionator. The stream containing coarse sand is filtered. The sand is stripped with kerosine which is then fed to the fractionator together with the filtrate at intermediate points. The fractionation produces gas, gasoline, kerosine and various cuts of oil including heavy bottoms which are recycled to the coker and heavy gas oil which can be recycled to the melt tank.

Marchant, L.C., C.S. Land and C.Q. Cupps. Activity on the Production of Energy From Tar Sands of the United States. (Energy Research and Development Administration, Laramie, WY). pp 763-780 of In Future supply of nature-made petroleum and gas. Meyer, R.F. (ed.). Elmsford, NY; Pergamon Press Inc. (1977).

Known tar sand deposits in the U.S. contain an estimated 24 to 30 x 10⁹ barrels of oil-in-place. Nearly 90% of this resource is in Utah and is contained in six deposits large enough to support production projects. Present technology is only in the experimental stage. Early commercial tar sand oil production efforts will probably consist of mining-plant extraction processes in the minor portion of the known resource with thin overburden and will require predominantly application of the yet-to-be-proven insitu technology.

Maxwell, J. Developing New Energy Sources: The Syncrude Case. Montreal; Howe Research Institute (1975). p. 30.

Results of a research project to produce oil from the Athabasca oil sands indicate that Canada's energy needs and present dependence on imported oil will be better served by a vigorous conservation effort. The Syncrude Canada Limited project suffered from escalating construction and operating costs of \$20,000 per barrel (compared to \$6,000 for North Sea development), which could make the process non-competitive in the 1980's market. A joint business and government venture was used because of the high investment risks, but this could set a precedent for future government modification of a profit-based market system. With investors delaying further projects until Syncrude's operations have progressed at least a year, oil production will fall off before the process can make a significant contribution to depleted domestic reserves. Canada's energy policy must determine whether to pursue the high risks of Syncrude expenses, oil import security, or uncertain Arctic exploration. The project also faced serious social problems in providing satisfying living and working conditions for 1800 permanent staff and their families.

Meyer, R.F. (ed.). Development Status of Alberta Oil Sands: 1976. pp. 731-762 of In Future supply of nature-made petroleum and gas. Elmsford, NY; Pergamon Press Inc. (1977).

Commercialization of the oil sand deposits in Alberta began only in the first half of 1976. For those deposits close enough to the surface for surface mining, the Hot-Water Process was selected for the first two commercial projects. Great Canadian Oil Sands presently produces 50,000 barrels per day. Syncrude Canada Limited is building a 100,000-bbl/day plant to be operational in 1979. The paper examines world reserves, research in technology, Canada's first surface-mining extraction plant, and future oil sands development.

Nicholls, J.H. and R.W. Luhning. Heavy Oil Sand Insitu Pilot Plants in Alberta (past and present). (Alberta Oil Sands Technol and Res Auth). J. Can. Pet. Technol.; 16: No. 3, 50-60(1977).

This paper reviews the history of in situ pilot plant efforts toward the recovery of bitumen from the major oil sand deposits of Alberta. The review is based on published information and describes the location of the plants, the manner of operation, the

estimated costs involved and the technical area under investigation. The currently operating pilot plants and future plans for new in situ pilots are also described. 50 refs.

Todd, J.C. Electrode Well for Electrically Heating a Subterranean Formation. (to Petro Canada Exploration Inc.). US Patent 4,084,639. 18 Apr 1978.

An improved electrode for electrically heating a subterranean formation includes a plurality of electrically conductive rod-like members that extend outwardly from a central well bore to provide increased area for conducting electrical current from a source into said subterranean formation. The improved electrode apparatus is adapted to be lowered into a well bore which has been drilled into the subterranean formation and, thereafter, the plurality of rod-like members are driven outwardly from the central well bore. Guide means are provided to direct the rod-like members outwardly into the subterranean formation as a central member is forced downward.

Trevoy, L.W., R. Schutte and R.R. Goforth. Development of the Heavy Minerals Potential of the Athabasca Tar Sands. (Syncrude Canada Ltd., Edmonton, Alberta). CIM Bull.; 71: No. 791, 175-180(Mar 1978).

Titanium- and zirconium-heavy minerals occur in the tailings streams from processing plants which use the hot-water extraction process for recovery of bitumen from tar sand. In a research program conducted by Syncrude Canada Limited, the crude tailings stream was upgraded to produce quality zircon and titanium mineral products. To process the tailings through conventional upgrading equipment, bitumen residues must first be removed from the mineral grains. Then, by gravity separation, fine and coarse sand grains were removed and a 71 percent heavy minerals concentrate was prepared which was further separated by high-tension equipment into zircon and titanium minerals concentrates. The zircon concentrate was upgraded by gravity, magnetic and high-tension cleaning to produce a high-quality 98 percent zircon product. The titanium minerals concentrate was separated into rutile, leucoxene and ilmenite fractions. Heavy minerals distribution in tar sand drilling core samples has been evaluated for various locations on Syncrude Lease 17, and expected annual production levels of heavy minerals have been estimated. A preliminary evaluation has been made of the potential for zircon, leucoxene and rutile production and for further upgrading of ilmenite and leucoxene to synthetic rutile for titanium dioxide pigment production.

Vermeulen, F.E. and F.S. Chute. Electrical Extraction of Oil From Tar Sand. (Univ. of Alberta, Edmonton, Canada). IEEE Trans. Ind. Appl.; IA-13: No. 6, 604-607(1977).

A new technique for the separation of bitumen from tar sand is described. In this technique an electrical current is passed through a quantity of tar sand which is positioned in a vessel

beneath a column of water. The passage of current causes the tar sand and the lower portion of the water column to become violently agitated and to eject particles of bitumen and sand. The bitumen particles rise to the surface of the water where they combine to form a froth. The sand particles rise only a short distance and then fall back towards the bottom of the vessel. Figures for energy balance and for the composition of the extracted bitumen and the tailings are given for laboratory scale experiments. The technique is compared to the commercially used hot-water separation process.

Yen, T.F. Shale Oil, Tar Sands, and Related Fuel Sources. Washington, DC; American Chemical Society (1976). p. 190.

Fourteen papers were presented at the symposium on oil shales, oil sands, desulfurization, chemical modification of bitumens, shale hydrocracking, and ozokerites. A separate abstract was prepared for each paper.

Zeama, H.R. Utah's Tar Sand Resource: Geology, Politics, and Economics. (Utah Geological and Mineral Survey, Salt Lake City).

Twelve of fifty deposits of oil-impregnated rock in Utah contain 98 percent of the 26 billion barrels estimated in place. This is about 90 to 95 percent of the total mapped U.S. resource. Several deposits have been and are mined for paving material. Extraction of two or three deposits is beginning or is proposed. Further developments are caught up in a tangled web of politics, legal and environmental considerations, technologic problems, economics, geography, and biology.

Environmental Impacts

Frazier, N.A., D.W. Hissong, W.E. Ballantyne and E.J. Mazey. Production and Processing of U.S. Tar Sands: An Environmental Assessment. Final report. (Battelle Columbus Labs., Ohio (USA)). Dec 1976.

Factors traceable to the increasing shortfall in U.S. production of natural crude have rekindled interests in U.S. tar sands as a source of synthetic fuel. Reported here are the results of a preliminary study to assess the potential primary environmental impacts of production and processing of U.S. tar sands bitumen. With the possible exception attributable to chemical differences between tar sand bitumen and coal, potential environmental impacts of producing tar sands by mining methods would be similar in type to those of mining coal by the same method and in the same area as the tar sand deposit. Processes for extracting bitumen from the mined tar sand would generate solid waste in the form of spent sand. Constituents and quantities of emissions to air and water are process dependent, but existing control technology and good environmental practices are technically applicable. A viable in situ production technology for producing tar sand reservoirs has not yet been demonstrated. On the basis of methods tested to date, potential environmental impacts of producing tar sands by in situ methods would be very similar to those of conventional oil field production. Technical and economic factors will determine if in situ methods, or possibly underground methods, are an alternative to surface mining in environmentally sensitive areas.

Environmental Impacts-Socio-Economic

Keeley, M. Fort McMurray Reaching Explosion Point. Can. Pet.; 16:
No. 12, 30-34 (Dec 1975).

A discussion covers problems in the town of Fort McMurray, Alberta, resulting from rapid population growth due to operation of the nearby Great Canadian Oil Sands Ltd. plant and construction of the adjacent Syncrude Canada Ltd. plant; and inadequate rail facilities for transportation of sulfur and coke produced at these plants and at other oil sands plants which might be built in the Athabasca area.

Production Technology

Provo, Utah. First Rocky Mountain Fuel Symposium.
Proceedings of a conference held January 30, 1976, in Provo, Utah.
(Brigham Young Univ., Provo, Utah (USA)). 30 Jan 1976. p. 12.

This symposium brought together top technical experts in the intermountain area to present and discuss data concerning coal, gas, tar sands, and oil shale. This compilation includes abstracts only of 27 papers. Two papers were given in the General Session on in situ experiments at the Laramie Energy Research Center and on overburden handling at surface coal mines. Session A entitled: Gasification, In situ Recovery and Related Studies, contained 12 papers, most relating to in situ recovery. Session B, Fossil Fuel Liquids, Combustion of Fossil Fuels, and Catalyst Studies, contained 13 papers, most of the papers relating to coal analysis, combustion, processing, etc.

In Situ Effort Gaining Momentum. Energy Process./Can.; 68: No. 1,
44-46(1975).

Current activities to unlock up to 164 billion bbl of reserves in tar sands by in situ production are the most concentrated research effort ever seen in tar sands. Current estimates place a commercial in situ project of 125,000 bbl/day at about the same cost as the equivalent producing capacity of the Syncrude project, over \$2 billion.

Washington, D.C. Stimulation of Oil and Gas Production. (Bureau of Mines, Washington, D.C. (USA)). p. 67.

The Bureau of Mines proposes this research program on methods of stimulating the production of petroleum and natural gas through: (1) secondary and tertiary methods, (2) non-nuclear fracturing methods, and (3) heavy-oil and tar-sand production methods. The proposed program covers a 5-year period at a total Federal funding cost of \$139.1 million and an average annual cost of \$27.8 million. Funds needed for the first year of the research program amount to \$23.7 million. The proposed program is based on a cooperative effort with industry, under which industry will make available the following: wells, pipelines, some equipment-such as pumps, compressors, and tanks, and scientific and engineering advice and services. Field work will be performed under contracts with industrial companies. Backup laboratory research will be performed partly by the Bureau of Mines and by universities through grants. The program will be fully coordinated with energy-research activities of other Interior Department agencies and the Atomic Energy Commission. An

advisory committee will be utilized to review and make recommendations concerning requests for proposals, proposals submitted, plans for contracts and grants, and the overall progress of the research program. Backup laboratory research also will be conducted in Bureau of Mines and industry laboratories. Included in such research will be the development of accurate methods.

Abougoush, M.S. Commercial In Situ Project Economics and Sensitivities. (D and S Resource Engineering Ltd., Calgary, Alberta). pp. 8., Paper 7615 of In CIM/CSPG convention on enhanced recovery. Calgary, Alberta, Canada; Gulf Oil Canada Ltd. (1976).

The development of the oil sands deposits of Alberta will be required to sustain Canada's self sufficiency in crude oil, and development of these deposits will generate large revenues for both the Federal and provincial governments and, to an equal extent, for the developers. There are no commercial in situ projects currently in operation even though most of the oil-in-place must be recovered by in situ techniques. To stimulate the development of in situ projects, the Alberta Government, through the Alberta Oils Sands Technology and Research Authority (AOSTRA), has made available to industry a \$100 million fund to be used for in situ experimental purposes. This paper examines a hypothetical in situ commercial project and presents a summary of the economics under today's environment. Sensitivities to various economic parameters are presented to illustrate the areas in which the developer can best maximize his profits through continued research. Economic sensitivities are also presented to show the effect on the project economics of changing the values of certain key factors over which the operator has little or no control.

Allen, J.C. Method of In Situ Recovery of Viscous Oils and Bitumens. (to Texaco Inc.). US Patent 4,026,358. 31 May 1977.

A method is given for recovering low-gravity viscous oils and bitumen hydrocarbons from a subterranean hydrocarbon-bearing formation by injecting thereinto a hydrocarbon solvent saturated with a gas, and thereafter establishing a thermal sink in the formation, followed by a soak period, and production of the hydrocarbons therefrom. 14 claims.

Allen, J.C. Oil Recovery Process Utilizing Aromatic Solvent and Steam. (to Texaco Inc.). US Patent 4,068,716. 17 Jan 1978.

Petroleum may be recovered from viscous petroleum containing formations including tar sand deposits by first creating a fluid communication path in the formation, followed by injecting via an injection well an aromatic solvent such as benzene, saturated with carbon dioxide at the injection pressure into the fluid communication path, following the injection of the solvent with the injection of an oil-displacing fluid such as hot water, steam, or superheated steam and recovering oil from the formation via a production well. If desired, the oil displacing fluid may include a solubilizing agent, a surfactant or an alkaline agent.

Allen, J.C. Recovery of Bitumens by Imbibition Flooding. (to Texaco Inc.). US Patent 3,978,926. 7 Sep 1976.

A method for recovering bitumen from tar sand deposits by imbibition flooding at ambient temperature is reported. The bitumen is sequentially contacted with a paraffin liquid hydrocarbon followed by a soak period to allow imbibition of the solvent, after which the bitumen and solvent mixture is produced, and the cycle is repeated.

Allen, J.C. and C.D. Woodward. Recovery of Petroleum From Viscous Asphaltic Petroleum Containing Formations Including Tar Sand Deposits. (to Texaco Inc.). US Patent 4,042,027. 16 Aug 1977.

Petroleum materials may be effectively recovered from subterranean, viscous, asphaltic or bituminous formations such as tar sand deposits by first injecting into the tar sand formation a paraffinic hydrocarbon at a temperature below 300°F which precipitates asphaltic material from the asphaltic petroleum in the formation. Next, solvent injection is terminated and air is injected into the formation, and the formation is ignited to accomplish in situ combustion within the tar sand reservoir utilizing the precipitated asphaltic materials for fuel for the in situ combustion reaction. Reaction temperatures higher than normal in situ combustion temperatures are produced, facilitating thermal cracking and in situ hydrogenation to upgrade the produced crude within the tar sand reservoir.

Allen, J.C., and Y.M. Shum. Thermal Recovery Method. (to Texaco Inc.). US Patent 4,059,152. 22 Nov 1977.

A method for recovering low gravity viscous crude oil or bitumen from a subterranean formation comprises first injecting superheated steam, next initiating an in situ combustion by injecting air, followed by an in situ combustion wherein both superheated steam and air are injected, then simultaneously performing an in situ combustion by injecting air while also injecting water and finally injecting water. 4 claims, 4 figures.

Anderson, D.J., C.F. Kirkvold, P. Pisio and J.R. Lishman. Recovering Viscous Petroleum From Thick Tar Sand. (to Chevron Research Co.). US Patent 3,994,341. 30 Nov 1976.

Recovery of viscous petroleum such as from thick tar sands is assisted using a closed-loop flow path from the earth's surface through a substantial portion of the formation for conducting hot fluid to reduce the viscosity of the petroleum in the formation. This develops a potential passage in the formation outside the flow path into which a drive fluid is injected to promote movement of the petroleum to a production position.

Arscott, R.L. and A. David. Evaluation of In Situ Recovery of Tar Sands. (Gulf Research and Development Co., Pittsburgh). 1977.

Several field tests of in situ recovery of tar and heavy oil expose the difficulty of achieving an acceptable economic process. The technical problems encountered in achieving successful projects are: adequate communication between wells, mobilization of the tar, and maintenance of production wells. If currently available technology for the recovery of tar sand is to compete economically with world prices for other resources, only the highly saturated, thick tar zones can be considered. The Alberta and Venezuelan resources qualify, but much of the U.S. resource is of questionable value.

Barrett, G.M. Fluid Carrier Recovery System and Method. US Patent 4,033,412. 5 Jul 1977.

This disclosure relates to a fluid carrier recovery system for recovering oil and like liquid deposits from an underground source wherein the oil is deposited in an unpumpable form and wherein the oil is recovered by directing into the oil deposit a carrier which will fill a large volume of the oil deposit and which will flow upwardly through a flow passage in the earth to a location adjacent or above the surface of the earth. This is followed by the introduction into the lower part of such volume of a solvent for the oil, the solvent having a lesser specific gravity than the carrier and being operative on the oil to form oil-solvent droplets which float in the carrier and flow to the top of the flow passage for recovery. The carrier is preferably water and the solvent may be an inexpensive mineral spirit immiscible with water.

Barry, C.B. In Situ Recovery of Hydrocarbons From Tar Sands. (to Ralph M. Parsons Co.). US Patent 3,945,435. 23 Mar 1976.

Hydrocarbon products from viscous tar sands are recovered by continuously injecting a hot solvent containing relatively large amounts of aromatics into the formation. Alternatively, steam and solvent are cyclically and continuously injected into the formation to recover the values. The last stimulation is by steam so that solvent is recovered. A third alternative is to continuously inject a mixture of steam and solvent vapors and liquid into the formation. In all cases, the solvent, except perhaps for startup, is produced at the site as in a conventional topping unit which alternatively is combined with a conventional visbreaking or reforming unit to increase the volume and/or aromaticity of the solvent produced.

Barry, C.B. In Situ Recovery of Hydrocarbons From Tar Sands. (to Ralph M. Parsons Co.). US Patent 3,946,810. 30 Mar 1976.

Hydrocarbon products from viscous tar sands are recovered by continuously injecting a hot solvent containing relatively large amounts of aromatics into the formation. Alternatively, steam and

solvent are cyclically and continuously injected into the formation to recover the values. The last stimulation is by steam so that solvent is recovered. A third alternative is to continuously inject a mixture of steam and solvent vapors and liquid into the formation. In all cases, the solvent, except perhaps for startup, is produced at the site as in a conventional topping unit which alternatively is combined with a conventional visbreaking or reforming unit to increase the volume and/or aromaticity of the solvent produced.

Bennion, D.W., L. Vorndran, J.K. Donnelly and R.G. Moore. Fireflooding Changes in Athabasca Bitumen and Water Properties. (Univ. of Calgary, Alberta). Am. Chem. Soc., Div. Fuel Chem. Prepr.; 22: No. 3, 158-170(1977).

Data are presented from the analysis of the effluent of a dry combustion test and a wet combustion test performed on oil sands from the Athabasca Oil Sands deposit. A brief description is given of the apparatus used to run the tests, as well as a description of the analytical methods used to do the effluent analysis and a discussion of the results obtained. It was concluded that thermal cracking, combustion gas reactions, and hydrogenation caused a reduction in the sulfur content of the produced oil and an upgraded oil with a higher H/C ratio, lower density, lower viscosity, and lower asphaltene content. The sulfur removed from the oil is mainly produced as acid, water, and a small amount of H_2S . The produced water contains up to 7,200 mg/l of dissolved organic carbon.

Bogopol'skii, A.O. and Ya.A Sharifov. Propagation of the Burning Front of Oil in a Porous Medium. Combust., Explos. Shock Waves (USSR) (Engl. Transl.); 12: No. 1, 6-12(1976).

The burning of oil in a porous medium has been examined in the context of the problem of intensifying the development of oil deposits. The results of an experimental study of the rate of propagation of a plane burning front of oil, depending on the filtration rate of the oxidizer, pressure, oil density, and degree of water saturation of the porous space are given. 12 refs.

Burnett, A.I. and K.C. Adams. Geological, Engineering, and Economic Study of a Portion of the Lloydminster Sparky Pool, Lloydminster, Alberta. (Murphy Oil Co. Ltd., Calgary, Alberta). Bull. Can. pet. Geol.; 25: No. 2, 341-366(May 1977).

A tidal-bar model for the deposition of the Sparky Sandstone at Lloydminster is presented and is related to the geology of a portion of the Lloydminster Sparky pool. An engineering and economic evaluation to determine the feasibility of redeveloping this suspended pool is undertaken. This study indicates that installation of a water-injection scheme immediately following a short production evaluation is economically viable. Economics of a tertiary thermal

scheme for the pool are presented on the assumption that present technological problems such as production of high-viscosity emulsions and sand have been overcome. Indications are that the incentive for further research into the solution of these problems is significant. Installation of thermal-recovery schemes in this pool can be expected to increase recoverable reserves by 15,000,000 barrels.

Cram, P.J. and D.A. Redford. Thermal Recovery of Hydrocarbons from Tar Sands. (to Texaco Exploration Canada Ltd.). US Patent 3,993,132. 23 Nov 1976.

A method is described for the recovery of low API gravity viscous oils or bitumen from a subterranean formation by the injection of a mixture of an oxygen-containing gas and steam having an optimum gas/steam ratio that is decreased as the cumulative amount of steam is increased. 10 claims, 1 figure.

Crawford, R.J., C. Spyckerelle and D.W.S. Westlake. Biodegradation of Oil Reservoirs. (Univ. of Alberta, Edmonton). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 22: No. 3, 204-208(1977).

The effects of microbiological degradation on several conventional pooled oils and on oil sand bitumens were studied. Samples of a Prudhoe Bay (PB) crude were examined for comparison with Lower Cretaceous pooled oils such as Bellshill Lake (BH) and Lloydminster, (LI) along with oil sand bitumens from the Cold Lake (CL), Peace River (PR) and Athabasca oil sands. The gas chromatography-mass spectroscopy processes reveal close similarities between the biodegradation products of the oil from Prudhoe Bay and the oil sands and heavy oils of Alberta. A common source for all of these oils is not postulated, although they probably share a similar origin and diagenetic history. These results do not give a direct indication as to the maturity and thermal history of the Alberta oil sands but they do support the hypothesis that the oil sands and some conventional crude oils can be found in the reservoirs of the Lower Cretaceous.

Decora, A.W. and L.A. Schrider. In Situ Recovery of Fossil Energy Resources. (Energy Research and Development Administration, Laramie, WY). Proc., Am. Pet. Inst., Sect. 3; 55: 53-65(1976).

The terminology "in situ recovery of fossil energy resources" as used today commonly refers to the conversion of a fossil energy resource into liquid and gaseous fuels in the place in which the resource occurs. Generally, these resources, whether they be oil shale, coal or tar sands, are either of low grade or are too inaccessible to be effectively recovered by conventional mining or other recovery techniques. In situ recovery may also be environmentally, economically and occupationally more attractive. Moreover, a significant portion of the nation's energy resources are well suited for in situ development. With the shortfall of energy projected for the future, the government, under ERDA, has accelerated its program in research and development and demonstration of in situ recovery of fossil energy resources. In particular the

Laramie Energy Research Center is engaged in research programs investigating the in situ development of oil shale, coal and tar sands. Ongoing field programs have illustrated the feasibility of utilizing in situ technology to recover these vast resources. These findings are presented along with areas of research which must be addressed before this technology can be advanced to the commercial stage.

Dewell, R.R. In Situ Extraction of Asphaltic Sands by Counter-current Hydrocarbon Vapors. US Patent 4,067,391. 10 Jan 1978.

A plurality of radially-extending horizontal conduits direct heated hydrocarbon vapors into the formation. The vapors are selected to have a boiling point above the pour point of the viscous oil. Thus, as the vapors rise in the formation, they will be in heat exchange relationship with the viscous oil to cause the latter to flow downward. In addition to the thermal exchange of energy, the vapors will move toward molecular equilibrium with the viscous oil formation.

Dorrence, S.M., K.P. Thomas, J.F. Branthaver and R.V. Barbour. Analyses of Oil Produced During In Situ Reverse Combustion of a Utah Tar Sand. (Laramie Energy Research Center, WY). Prepr., Div. Pet. Chem., Am. Chem. Soc.; 22: No. 2, 729-732(Mar 1977).

An in situ recovery experiment was conducted in the Northwest Asphalt Ridge deposit near Vernal, Utah. Reverse combustion was used for the recovery of tar sands hydrocarbons. The field experiment produced liquid organic, aqueous, and gaseous materials. This paper describes the detailed characterization of product oils from the experiment and compares the data to those obtained on bitumen extracted from core samples taken prior to the burn. The light oils produced during the reverse combustion were upgraded considerably compared to the original bitumen, and the heavy oils are very similar to the bitumen.

Farouq Ali, S.M. Bitumen Recovery From Oil Sands, Using Solvents in Conjunction With Steam. (Pennsylvania State Univ., University Park); Abad, B.J. Can. Pet. Technol.; 15: No. 3, 80-90(1976).

Results of an experimental investigation of bitumen recovery from Athabasca oil sand, using solvents in conjunction with steam, are discussed. Most of the runs were carried out in a vertical tar sand pack, with restricted fluid entry near the bottom of the pack, simulating conduction-convection heating with gravity flow. A few runs were conducted in a large three-dimensional model of a five-spot configuration. The synthetic crude manufactured by Great Canadian Oil Sands Ltd. was the principal solvent used. A few runs employed naphtha and the "Mobil Solvent." Actual Athabasca oil sand was used to pack the models, which did not permit scaling. It was found that bitumen recovery is determined by the type of the solvent, the volume used, and the solvent placement. For examples, when the solvent was injected into the producing well, followed by steam injection into the injection well, the recovery was much

higher than when both solvent and steam were injected into the same well. The water-bitumen ratio was higher in this latter case than in the previous injection scheme. The bitumen recovery tended to be higher when using naphtha, however, breakthrough occurred rapidly in this case. Also, naphtha caused asphaltene precipitation in several instances. The GCOS synthetic crude did not have these problems, and yielded higher bitumen-solvent ratios. The Mobil solvent matched the performance of the other two solvents, in different respects.

French, G.B. In Situ Recovery of Shale Oil. (to Occidental Oil Shale, Inc.). US Patent 4,043,595. 23 Aug 1977.

An in situ oil shale retort is formed in a subterranean oil shale deposit by excavating a columnar void having a vertically extending free face, drilling blasting holes adjacent to the columnar void and parallel to the free face, loading the blasting holes with explosive, and detonating the explosive in a single round to expand the shale adjacent to the columnar void toward the free face in layers severed in a sequence progressing away from the free face and to fill with fragmented oil shale the columnar void and the space in the in situ retort originally occupied by the expanded shale prior to the expansion. A room having a horizontal floor plan that coincides approximately with the horizontal cross section of the retort to be formed is excavated so as to intersect the columnar void. The blasting holes are drilled and loaded with explosive from the room. The room can lie above the columnar void, below the columnar void, or intermediate the ends of the columnar void. In one embodiment, the columnar void is cylindrical and the blasting holes are arranged in concentric rings around the columnar void. In another embodiment, the columnar void is a slot having one or more large parallel, planar vertical free faces, toward which the oil shale in the retort under construction can be explosively expanded. The blasting holes are arranged in planes parallel to these faces. The resulting retort generally has a cross section coinciding with the placement of the blasting holes and a height determined for the greater part by the vertical height of the columnar void. To form a retort having a large cross-sectional area, a plurality of columnar voids can be excavated and the shale in the retort expanded toward the respective columnar voids to form a continuous fragmented permeable mass of oil shale.

Fisher, S.T. Electrical Induction Heating: A New Concept in In Situ Recovery. (F.T. Fisher's Sons Ltd., Montreal). Energy Process./Can.; 70: No. 1, 42-46, 48(1977).

The new processes involve little or no surface disturbance, no hydraulic, shale, or sand tailings, and a minimum of thermal pollution. Processes proceed with no regard to the weather. There is no requirement for water supply, but water derived from the deposit can be disposed of to ecological advantage. The sulfur problem is unchanged. The surface plant can be located directly over the deposit. Where the deposit occurs in several layers separated by

sedimentary materials, it can be worked as readily as an equivalent thick seam. There is no human hazard at the surface or in the central shaft from the electromagnetic field.

Fisher, S.T. and C.B. Fisher. Method for Induction Heating of Underground Hydrocarbon Deposits Using A Quasi-toroidal Conductor Envelope. US Patent 4,008,761. 22 Feb 1977.

A method of heating hydrocarbons in situ in an underground hydrocarbon deposit such as bituminous sands or oil shale is described. A selection part of the deposit is heated by electrical induction coils arranged in a quasi-toroidal configuration to temperatures high enough to facilitate extraction. The coils are preferably comprised of interrupted rectangular turns. A series of generally concentric quasitoroidal configurations can be used to heat large volumes. A hexagonal honeycomb array of such configurations can be used to heat deposits underlying very large surface areas. 8 claims, 7 figures.

Giguere, R.J. In Situ Recovery Process for the Oil Sands of Alberta. (Amoco Canada Petroleum Co. Ltd., Calgary, Alberta). Energy Process./Can.; 70: No. 1, 36-40(1977).

This paper reviews Amoco Canada's past 20 years of research effort in the laboratory and in the field. Discussed are the six phases of field work undertaken and resultant in situ recovery processes developed. Results are: a successful producing well completion, a successful air injection well completion, a heat and corrosion resistant alloy, and developed thermal stimulation techniques for the producing wells. A three-step in situ process is foreseen for the recovery of the Athabasca bitumen: a pre-heat phase via forced forward combustion with injection above overburden pressures, a flowdown phase, and COFCAW (combination of forward combustion and waterflood) displacement phase.

Glassett, J.M. and J.A. Glassett. Production of Oil From Intermountain West Tar Sands Deposits. Mar 1976. p. 91. Research Institute, Provo, Utah.

Six tar sand deposits in the Intermountain West, each containing more than one billion barrels of oil in place, are identified. All of these deposits are in eastern Utah and contain a total of twenty-eight billion barrels of oil. The names of the six deposits arranged in descending order of desirability for large-scale surface-mining oil recovery operations are as follows: Sunnyside, Tar Sand Triangle, Asphalt Ridge, P.R. Spring, Circle Cliffs, and Hill Creek. An overview of each deposit is presented including geology, surface-mining variables, chemical processing variables, environmental aspects, and economics. A comparison of Utah tar sands and Athabasca, Alberta, Canada tar sands is also presented.

Harnsberger, B.G. Processes for Producing Bitumen From Tar Sands and Methodology for Forming a Gravel Pack in Tar Sands. (to Amoco Inc.). US Patent 4,066,127. 3 Jan 1978.

Kendall, G.H. Importance of Reservoir Description in Evaluating In Situ Recovery Methods for Cold Lake Heavy Oil. Part I. Reservoir description. (Imperial Oil Ltd., Calgary, Alberta). pp. 8., Paper 7620 of In CIM/CSPG convention on enhanced recovery. Calgary, Alberta, Canada; Gulf Oil Canada Ltd. (1976).

The huge reserves of heavy oil in Alberta are found in a variety of complex reservoirs. Recovery, excluding mining, will require application of some form of in situ recovery methods, primarily in the better reservoirs. The proper selection of an in situ method, applicable to the various reservoir types, requires a basic understanding of reservoir description and the engineering aspect of the reservoirs. In Part 1 of this paper, reservoir description in the Cold Lake heavy oil deposits is discussed under three headings: (1) Rock Properties, (2) Fluid Saturation, and (3) Reservoir Geometry. Based on these parameters, five selected reservoir types are discussed and compared. Part 2 considers the application of the reservoir description in evaluating in situ methods. The significance of the reservoir parameters is discussed in general terms and related to the four most important in situ recovery mechanisms: steam stimulation, steam drive, combustion, and solvent. The reservoir description is then used as the basis of comparison of the recovery mechanisms for each of the five Cold Lake reservoir types described in Part I.

Kendall, G.H. and D.E. Townson. Importance of Reservoir Description in Evaluating In Situ Recovery Methods for Cold Lake Heavy Oil--1, 2. (Imp Oil Ltd, Calgary, Alberta). Bull. Can. Pet. Geol.; 25: No. 2, 314-340(May 1977).

The huge reserves of heavy oil in Alberta are found in a variety of complex reservoirs. Recovery, excluding mining, will require application of some form of in situ recovery method, primarily in the better reservoirs. In Part 1 of this paper, reservoir description in the Cold Lake heavy-oil deposits is discussed under three headings: (1) Rock Properties, (2) Fluid Saturation, and (3) Reservoir Geometry. On the basis of these parameters, five selected reservoir types are discussed and compared. Part 2 considers the application of the reservoir description in evaluating in situ methods. The significance of the reservoir parameters is discussed in general terms and related to the four most important in situ recovery mechanisms: steam stimulation, steam drive, combustion and solvent. 14 refs.

Kropschot, R.H. and G.C. Phillips. Fossil Energy Research Meeting. (Energy Research and Development Administration, Washington, D.C. (USA). Div. of Physical Research). Dec 1977. p. 560.

U.S. ERDA's research programs in fossil energy are reviewed with brief descriptions, budgets, etc. Of general interest are discussions related to the capabilities for such research of national laboratories, universities, energy centers, etc. Of necessity many items are treated briefly, but a general overview of the whole program is provided.

Land, C.S., C.Q. Cupps, L.C. Marchant and F.M. Carlson. Field Test of Reverse Combustion Oil Recovery From a Utah Tar Sand. (Energy Research and Development Administration, Laramie, WY). p. 8., Paper 7603 of In CIM/CSPG convention on enhanced recovery. Calgary, Alberta, Canada; Gulf Oil Canada Ltd. (1976).

A field experiment to recover oil from tar sand by reverse combustion was conducted at Northwest Asphalt Ridge near Vernal, Utah. This test was in a 10-foot interval of the Rim Rock sandstone member of the Mesa Verde Formation at a depth of approximately 300 feet. Ignition was accomplished November 25, 1975, and the reverse combustion front was propagated successfully through the formation. Results of the field experiment differed significantly from the results of laboratory tests that were used in the design of the field test. This difference is attributed primarily to the extreme heterogeneity of the tar sand formation. Observed temperatures in the burned area were lower than expected, but a large portion of the tar sand within the pattern boundaries was heated to the extent that the bitumen became mobile enough to be produced. After 3 1/2 weeks of operation, the project was terminated because of the inability of the surface production equipment to accommodate the heavy hydrocarbons being produced. Although the formation of the cracked products of reverse combustion was less than expected, this recovery process may be used successfully to heat the tar sand reservoir to a temperature high enough that the bitumen becomes mobile enough to be produced.

Malden, M.L. Oil Sands In Situ Projects Continue at Impressive Rate. Energy Process./Can.; 70: No. 1, 24-26, 28-30, 32, 34(1977).

In situ research and pilot plant recovery projects continue to set the pace in experimental efforts to exploit the massive in-place reserves of Alberta's four major tar sands deposits. The projects include five active projects in the Athabasca deposit, eight current projects in the Cold Lake deposit, and one field investigation each in the Peace River and Wabasca deposits, to make a total of 15 active projects with more than 266 test wells.

Marchant, L.C., C.S. Land and C.Q. Cupps. Experimental Approach to In Situ Oil Recovery From Tar Sands. (Laramie Energy Research Center, WY). pp. 147-158 of In Resource recovery. Albuquerque, NM; American Society of Mechanical Engineers (1975).

The reverse combustion process has several features that make it attractive as an in situ oil recovery method for tar sands. One is the improved quality of the oil produced from the tar sand. Another is the flow of the heatproduced vapors through the heated sand, which obviates the possible sand plugging by liquids as might occur with forward combustion and other thermal recovery methods. There are disadvantages, however, that could prevent successful use of the method, such as the possibility of spontaneous ignition due to low-temperature oxidation during air injection through the tar sand and the limitation on pattern size imposed by low air permeability

of tar sands containing appreciable oil saturation. A field experiment will be conducted to evaluate the problems and limitations that would be encountered in attempts to apply the process on a much larger scale.

McCabe, J.T. and J.P. McGee. Evaluation of Pump Used for In Situ Oil Recovery From Tar Sands. (Mechanical Technology, Inc., Latham, N.Y. (USA)). 10 Nov 1977.

A field experiment is being conducted near Vernal, Utah for oil recovery from tar sands by in situ combustion. The principal mechanical problem was identified as repeated failure of the pumps used to lift the oil from the production wells. The primary problem plaguing the sucker-rod pumps is that the pump barrel frequently plugs with sand, and the pump must be pulled from the bottom of the hole to be cleared. Other problems were also encountered due to combustion of the elastor seal and pump, plugging from solidified bitumen, and wear. It is recommended that the gas lift method should be used to pump oil at this site, and for future sites hot-water and condensing-steam pumps should be compared with the sucker-rod pump.

McIntyre, H. Heavy Oil Recovery in the Alberta Oil Sands. Eng. J. (N.Y.); 59: No. 1, 61-65(1976).

A \$200,000,000 top-priority industry/government venture in development of Alberta's underground tar sands resources is to start by mid-1976, involving the Alberta Oil Sands Technology and Research Authority, established in mid-1975 and custodian of \$100,000,000 in provincial research and development funding to be put up on a 50-50 basis to the most promising industry field experimental schemes for in situ tar sands development. By the Nov. 1975 deadline, 21 proposals from seven integrated oil companies, one consortium, seven nonintegrated oil companies, and five individuals were received. The total initial bitumen in place is estimated by Alberta's Energy Conservation Board at 919 billion bbl, of which only 74 billion exists at surface mining depths, i.e., with less than 150 ft of overburden. The remaining 845 billion bbl must be tapped by drilling.

McIntyre, H. Oil Companies Push In situ Recovery. Can. Process.; 61: No. 7, 31-34(Jul 1977).

Possibly, a third Athabaska tar-sand plant using surface will be built in the 1980's, but future development beyond that point will probably depend on in situ recovery. The discussion of in situ recovery focuses on the effect it will have on the Canadian chemical industry, for example, the market for sodium hydroxide. To obtain the highest yields of oil from bitumen, an external source of hydrogen is necessary--for example, Syncrude imports natural gas to make hydrogen for desulphurization. Gasification of coal is a possible source of hydrogen. Research on hydrocracking is progressing. Use of a prototype CANDU OCR reactor to raise the hot steam necessary for in situ recovery has been suggested. Venezuela is interested in Canadian upgrading technology.

Mills, G.A. Advances in Fuel Chemistry. 1961-1974. (Office of Coal Research, Washington, DC). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 19: No. 3, 178-199(1974).

While major changes occurred in the amounts (50 percent increase), the greatest change was in character of fuels technology. A turnaround to a deficit supply of gas and oil brought new attitudes. New environmental concern caused major changes, e.g., switch from coal to electricity. While nuclear grew tenfold, less than two percent of U.S. energy was nuclear in 1974. Two major breakthroughs in petroleum refining were use of molecular sieves and bimetallic reforming catalysts. Hydroprocessing advanced to include petroleum residue. Petrochemical changes were many, e.g., products by pyrolysis and use of homogeneous catalysts. Research for conversion of coal to clean gas and liquid fuels took a quantum jump--seven large pilot plants were constructed to test new technology. Focus was on sulfur reduction chemistry, catalysis and engineering. Production of fuels from Athabasca tar sands began. Oil shale technology included in situ retorting, molecular structure studies, and upgrading of products. Related fuel chemistry was also important--combustion to minimize pollutants and also stack gas scrubbing.

Moore, R.G., D.W. Bennion and J.K. Donnelly. Laboratory Research on a Direct Heat Process for This Extraction. (Calgary Univ., Alberta). Energy Process./Can.; 68: No. 1, 48-56(1975).

Laboratory research on a direct-heat process for this extraction from oil sands will indicate if pilot-plant testing of the process on a larger scale is warranted. Combustion technology is similar to in situ recovery of bitumen by fire flooding. The requirement of a heat carrier for indirect heat processes would increase the complexity and cost of extraction equipment.

Moschopedis, S.E. and J.G. Speight. Oxidation of a Bitumen in Relation to its Recovery From Tar Sand Formations. (Research Council of Alberta, Edmonton). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 19: No. 2, 192-201(1974).

Simple chemical reactions are described which bring about modification of the components of a bitumen. This is accomplished by an in situ process using an oxygen-containing gas followed by treatment with alkali solutions of sulfites and/or bisulfites. The resulting water-soluble derivatives have significant emulsifying and dispersing powers.

Mungen, R. (Amoco Production Co., Tulsa, OK) and J.H. Nicholls. Recovery of Oil From Athabasca Oil Sands and From Heavy Oil Deposits of Northern Alberta by In Situ Methods. pp. 29-39 of In Ninth world petroleum congress. Volume 5. London; Applied Science Publishers Ltd. (1975).

There are vast reserves of bitumen in the oil sands of northern Alberta in the Athabasca, Wabasca, and Peace River areas. There

are also large reserves of heavy oil in areas like Cold Lake and Marten Hills. The chemical properties of bitumen and heavy oil are quite similar, but their viscosities are different. At the usual formation temperatures, bitumen is essentially immobile, while the heavy oils have some mobility. An in situ combustion process is described for recovery of oil from the Athabasca oil sands, and a second process is described which uses steam heating in the recovery of heavy oils.

Needham, R.B. Producing Heavy Oil From Tar Sands. (to Phillips Petroleum Co.). US Patent 4,068,717. 17 Jan 1978.

A method is provided for recovering heavy oil from an underground tar sand reservoir by injecting steam into an injection well penetrating the reservoir sufficiently to fracture the tar sand and provide passage for the steam through the tar sand to a production well piercing the tar sand reservoir. Steam is provided at sufficient heat to mobilize heavy oil from the permeated tar sand and a pressure sufficient to maintain competency of the formation to permit continued flow from the injection well to the production well. Injection of surfactant into the tar sand reservoir is used to produce a condensible foam which aids in maintaining back pressure on the injected steam within the tar sand reservoir to maintain the competency of the formation and to cause further permeation of the formation by the steam. Foam can be produced of strength sufficient to permit pressure to be applied in the tar sand reservoir capable of further fracturing the reservoir.

Perkins, T.K. Production of Bitumen From a Tar Sand Formation. (to Atlantic Richfield Co.). US Patent 3,958,636. 25 May 1976.

A method is described for producing bitumen from a subterranean tar sand formation while heating the formation via electrical conduction between a plurality of wells completed therein characterized by a plurality of steps. First, a high back pressure is maintained on the wells. Next, an immiscible fluid is injected into the formation through one of the wells. Thereafter, the bitumen is produced through one of the wells.

Puttagunta, V.R., R.O. Sochaski and R.F.S. Robertson. Role for Nuclear Energy in the Recovery of Oil From the Tar Sands of Alberta. (at Energy of Can Ltd, pinawa, Manit). J. Can. Pet. Technol.; 16: No. 3, 28-49(1977).

This report briefly describes techniques of oil recovery from the tar sands and the energy requirements of this operation. Fossil fuels, such as coal, and CANDU nuclear reactors are examined as competitive sources of energy for the tar sands plants. This study indicates the feasibility of both sources. Among the nuclear reactors, the organic-cooled version of the CANDU reactor appears to have the necessary flexibility to fit into many of the possible methods of recovering oil from the tar sands. A strategy is discussed for the recovery of oil from the tar sands with a view to optimizing the costs and, in the long run, to conserving the fossil fuels at the expense of nuclear fuels.

Redford, D.A. Development of Communication Paths Within Tar Sand Bed. (Product Research and Development, Edmonton, Alberta); Cotsworth, P.F. Am. Chem. Soc., Div. Fuel Chem., Prepr.; 19: No. 2, 224-230(1974).

The in situ methods for recovering bitumen from the Athabasca tar sands are dependent upon a successful development of a useable communication path. The major problem is blockage of the path due to slumping of the tar sand or cooling of the hot unemulsified bitumen when it enters a cold region. Blockage is particularly acute in the early stages of path development. In situ recovery methods are reviewed and two new approaches based on low-temperature emulsification are presented. Certain agents were found to promote emulsification at formation temperature (40°F). The other approach uses chemical reagents which react with the bitumen in the formation forming water-soluble surfactants. Subsequent injection of water results in their ready displacement, thus enlarging the path and alleviating blockage. It was demonstrated in the field and in the laboratory that by using a combination of nonionic surfactant and base (sodium hydroxide), and using pressures substantially below the propping pressure, a cold propped fracture path can be developed into a zone that will accept large volumes of steam without sealing. It was further demonstrated in the laboratory that ozone will readily react with bitumen at formation temperatures to form highly-oxygenated water-soluble surface-active agents. Therefore, it is anticipated that ozone together with water and/or dilute basic solutions can be used at low pressures to expand a propped fracture path into a hot communications path which will accept steam without sealing.

Redford, D.A. In Situ Gasification of Solid Hydrocarbon Materials in a Subterranean Formation. (to Texaco Exploration Canada Ltd). US Patent 4,026,357. 31 May 1977.

Solid hydrocarbon materials present in subsurface earth formation such as, for example, the coke-like residue remaining in a subterranean tar sand deposit which has previously been exploited by controlled oxidation depletion, is converted to a synthesis gas composition by contacting the solid hydrocarbon material with an oxygen enriched gas or essentially pure oxygen and a moderating fluid such as water, steam or carbon dioxide to control the reaction temperature so as to ensure the generation of carbon monoxide and hydrogen within the formation. The oxygen and steam or carbon dioxide may be injected as a mixture or simultaneously by separate injection means, or oxygen may be injected for intervals of time interrupted by brief periods of carbon dioxide, steam or water injection. The effluent is predominantly gaseous carbon monoxide, hydrogen, and lesser amounts of carbon dioxide and methane and, occasionally, liquid hydrocarbons. The mixture of carbon monoxide and hydrogen may be utilized directly as fuel gas or may be utilized as feed stock for petro chemical manufacturing processes. Carbon dioxide may be separated from the effluent gaseous mixture and recycled with steam into the formation. 16 claims, 1 figure.

Redford, D.A. Method For Recovery of Bitumens From Tar Sands. (to Texaco Exploration Canada, Ltd.). US Patent 3,978,925. 7 Sep 1976.

A method for the recovery of low gravity viscous oils or bitumens from a subterranean formation is described. It consists of the injection of a mixture of an oxygen-containing gas and steam to establish a hot communications path, followed by a shutting in of wells for a period to allow the oxygen to react with the oil or bitumen in the formation and thereafter recovering the oil or bitumens via the production well. The cycle may thereafter be repeated.

Rouston, W.G. In Situ Solvent Fractionation of Bitumens Contained in Tar Sands. (to Dow Chemical Co.). US Patent 4,022,277.

Bituminous hydrocarbons are recovered from unconsolidated tar sands by in-place, selective leaching with a hot condensate formed upon contact with hot solvent vapors injected in the formation. The composition and temperature of the vapors are regulated so that a less soluble fraction of the tar is left behind as a residue. This residue does not dissolve in the vapors passing through the already leached portion of the formation and continues to act as a sand-supporting and immobilizing agent. Thus, subsidence of the leached formation and release of sand grains (which tend to interfere with removal of the leachate from the formation) are avoided. Solvent for the process is obtainable by distillation or cracking of the produced bitumens. 10 claims, 1 figure.

Sande, W.N. Unconventional Oil. III. The Syncrude Project and the Future of Heavy Oil Development. (Syncrude Can Ltd, Edmonton, Alberta). Rev. Energ.; 28: No. 296, 116-130(Aug-Sep 1977).

This article summarizes the history of the tar sands, describes the geology in general terms, describes the Syncrude Project (Canada) from its inception and portrays the magnitude of the Project explaining the problems associated with large-scale tar sand recovery programs. With this background, the future of tar sand development, both mining and in situ, is discussed. The oil sands are present along a discontinuous northwest-southeast trend across northern Alberta from Peace River on the West to Cold Lake on the east. Between these two are the largest deposit at Athabasca, the Wabasca area, and other small accumulations. A slightly less viscous oil is present in the Lloydminster area where oil is being recovered by conventional means, aided by stimulation methods. The Athabasca oil sands, with about 625 billion barrels of oil-in-place, is the largest heavy oil sands accumulation in the world. Altogether, the long-term production potential from all the tar sands is 300 billion barrels of recoverable oil.

Schutte, R. Chemistry for Tar Sands Development. (Syncrude Research, Edmonton, Alberta). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 22: No. 3, 8-13(1977).

Research projects that would be beneficial to the oil sand industry are discussed. The merits and drawbacks of steam processing in the Syncrude process are examined along with the reliability of this process. Discussions of coking processes are also included along with hydrocracking and hydrodesulfurization technologies.

Simmer, M. and D.C. Thompson. Bitumen Upgrading: Its Importance to the In Situ Producer. pp. 12., Paper 7602 of In CIM/CSPG convention on enhanced recovery. Calgary, Alberta, Canada; Gulf Oil Canada Ltd. (1976).

This paper explores the substantial effect on the producing operation of the selection and design of upgrading and utilities plants in an in situ oil sands scheme. Oil sands bitumen contains large amounts of impurities which have to be removed in converting (upgrading) to synthetic crude. This upgrading increases the hydrogen-carbon ratio and removes the sulfur and nitrogen present in the crude bitumen. There are a number of processes that are suitable for bitumen upgrading. Several of the most promising processes are described, including schematic process flow diagrams and yield slates. The energy requirements of such an integrated producing-upgrading-utility complex are immense but can be significantly reduced by complete process integration of the facilities. Among the major energy consumers in the upgrading-utility complex are the hydrogen plant and electric power generating equipment. The nonlinear relationship of conversion (upgrading bitumen feed to synthetic crude) to overall (produced bitumen to synthetic crude) recovery is demonstrated by two examples of the same process. Economic factors are examined qualitatively in the last part of this paper.

Simmer, M. and D.C. Thompson. Bitumen Upgrading--Its Importance to the In Situ Producer. (In Situ Res and Eng Ltd, Edmonton, Alberta). J. Can. Pet. Technol.; 16: No. 2, 49-53(Apr-Jun 1977).

This paper explores the substantial effect on the producing operation of the selection and design of upgrading and utilities plants in an in situ oil sands scheme. Oil sands bitumen contains large amounts of impurities which have to be removed in converting (upgrading) to synthetic crude. This upgrading increases the hydrogen-carbon ratio and removes the sulfur and nitrogen present in the crude bitumen. There are a number of processes which are suitable for bitumen upgrading. Two of the most promising processes are described, including schematic process flow diagrams and yield slates. 3 refs.

Shuck, L.Z., G.E. Fasching, J.W. Martin and L.A. Bissett. In Situ Hydrocarbon Recovery Simulation Laboratory Research at Morgantown Energy Research Center. 1976.

The development of in situ recovery processes whether in coal, oil shale, tar sands, petroleum and natural gas or geothermal-type reservoirs can proceed along various paths. The most direct approach

of immediately attempting a field-based recovery scheme is by far the most productive and enlightening into the real practical problems associated with the particular chosen reservoir and recovery scheme. However, even with substantial theoretical and practical engineering support, there are not only cost obstacles, but in some processes, limitations as to what can be observed from the field studies. By virtue of the remoteness, frequently only black-box input/output quantities are observable and measurable such that the real internal processes can only be hypothesized. Rudimentary field tests may quickly achieve a process efficiency plateau, which even through trial and error, may not be greatly improved upon. Further development may then depend upon a more basic scientific approach. This is the essence of the In Situ Hydrocarbon Recovery Simulation Laboratory developed at the Morgantown Energy Research Center. Improvement in the overall total energy resource recovery efficiency of only a few percent could mean the difference of whether UCG is utilized in the U.S. on a large commercial scale.

Smith, C.D. and D.V. Keller, Jr. Methods of and Apparatus for Mining and Processing Tar Sands and the Like. (to Standard Oil Co.). US Patent 4,067,616. 10 Jan 1978.

Described are methods of and apparatus for recovering bitumen from tar sands and the like in which the tar sand is mechanically dislodged from the formation in which it is deposited and in which a solvent for the bitumen is mixed with the mined material to reduce the viscosity of the bitumen and thereby facilitate the transfer of the mined material to an operation where the bitumen is separated from solid components of the tar sand.

Striegler, J.H. and E.P. Howell. Recovery of Bitumen From Tar Sands (to Atlantic Richfield Co.). US Patent 4,007,788. 15 Feb 1977.

A method of recovering bitumen from a subterranean tar sand formation is described, characterized by a plurality of steps. First, a continuous wellbore having a second section thereof contained within the formation and first and third sections thereof extending the second section to the earth's surface is formed. Next, the first and third sections of the wellbore are cased. Thereafter, a heated fluid is circulated through the wellbore contacting the formation to reduce the viscosity of the bitumen contained therein rendering the bitumen mobile. Subsequently, bitumen mobilized by the heated fluid is recovered via the wellbore. 1 claim, 1 figure.

Terwilliger, P.L. Fireflooding Shallow Tar Sands: A Case History. (Gulf Research and Development Co., Pittsburgh). pp 11., Paper 7608 of In CIM/CSPG convention on enhanced recovery. Calgary, Alberta, Canada; Gulf Oil Canada Ltd. (1976).

A field pilot test of forward combustion utilizing fracturing techniques was conducted in a shallow tar sand deposit in central Kentucky. The tar sand at a depth of 100 ft had an average porosity of 22%, an oil saturation of 64% (6.4% tar by weight) and a

permeability after extraction of about 2000 md. The tar had an API gravity of 10.4° and a viscosity of 150,000 cps at a reservoir temperature of 56°F. The pilot area was a small inverted five-spot 107 ft on a side. Horizontal fractures were created in the four producing wells by breaking down the formation with air pressure, and these fractures propped to a calculated radius of 25 ft by injecting water-base gel carrying 4 to 8 mesh sand. A pneumatic fracture was created in the central injection well which was held open by the continued injection of air. A down-hole burner was used to initiate the combustion zone. Oil production responded to the movement of the combustion zone ten days after the fireflood was started. The average oil production was 24 barrels per day for the four months required to complete the test. The total oil production of 3100 barrels was 54% of 5700 barrels originally in place in the pattern area. The injected air-produced oil ratio was 42,000 cu ft/bbl. The produced oil was upgraded to 14.5° API and 2000 cps at 60°F compared to 10.6° API and 90,000 cps for the original tar at the same temperature. The major problems encountered were the lack of complete oxygen consumption, the unsymmetrical advance of the fire-flood and the tendency of the combustion zone to move toward the top of the reservoir.

Todd, J.C. Method of Producing Viscous Materials from Subterranean Formations. (to Petro Canada Exploration Inc.). US Patent 4,084,637. 18 Apr 1978.

A method of producing viscous materials from subterranean formation comprises a plurality of steps. At least two wells are drilled and completed into the subterranean formation that contains the viscous material. At least one of the wells is completed as an injection well and one of the wells is completed as a production well. A plurality of electrode wells are drilled into the subterranean formation with the plurality of electrode wells being generally arranged in a pattern to define at least one path between the production well and the injection well with the length of the path being substantially greater than the distance between the production well and the injection well. The electrode wells are spaced apart along the path at distances that are substantially less than the distance between the production well and the injection well. Thereafter, a voltage is applied across the adjacent pairs of electrode wells to thereby cause an electrical current to pass through the subterranean formation between each adjacent pair of the electrode wells. As the electrical current passes through the subterranean formation, the viscous material is heated to thereby lower the viscosity of such material. Following the heating of the subterranean formation in the vicinity of the path formed by the electrode wells, a driving fluid is injected through the injection wells to thereby migrate along the path and force the material having a reduced viscosity toward the production well and, by continuing to inject a heated fluid through the injection wells, substantially all of the viscous material in the subterranean formation can be heated to lower its viscosity and be produced from the production well.

Towson, D.E. Importance of Reservoir Description in Evaluating In Situ Recovery Methods for Cold Lake Heavy Oil. Part I. In situ application. (Imperial Oil Ltd., Calgary, Alberta). pp. 8., Paper 7621 of In CIM/CSPG convention on enhanced recovery. Calgary, Alberta, Canada; Gulf Oil Canada Ltd. (1976).

The huge reserves of heavy oil in Alberta are found in a variety of complex reservoirs. Recovery, excluding mining, will require application of some form of in situ recovery methods, primarily in the better reservoirs. The proper selection of an in situ method, applicable to the various reservoir types, requires a basic understanding of reservoir description and the engineering aspect of the reservoirs. In Part 1 of this paper, reservoir description in the Cold Lake heavy oil deposits is discussed under three headings: (1) Rock Properties, (2) Fluid Saturation, and (3) Reservoir Geometry. Based on these parameters, five selected reservoir types are discussed and compared. Part 2 considers the application of the reservoir description in evaluating in situ methods. The significance of the reservoir parameters is discussed in general terms and related to the four most important in situ recovery mechanisms: steam stimulation, steam drive, combustion and solvent. The reservoir description is then used as the basis of comparison of the recovery mechanisms for each of the five Cold Lake reservoir types described in Part 1.

Towson, D.E. Importance of Reservoir Description in Evaluating In Situ Recovery Methods for Cold Lake Heavy Oil. Part 2. In situ application. Bull. Can. Pet. Geol.; 25: No. 2, 328-340 (May 1977).

The application of the reservoir description in evaluating in situ methods is considered. The significance of the reservoir parameters is discussed in general terms and related to the four most important in situ recovery mechanisms: steam stimulation, steam drive, combustion, and solvent. The reservoir description is then used as the basis of comparison of the recovery mechanisms for each of the five Cold Lake reservoir types.

Wu, C.H. Method for Recovering Viscous Petroleum. (to Texaco Inc.). US Patent 3,997,004. 14 Dec 1976.

Disclosed is a method for recovering viscous oil from subterranean viscous-oil-containing formations, particularly from shallow formations which overlies water zones. An injection well is completed in the lower part of the oil formation and an equivalent amount in the water zone immediately therebelow, and the production well is completed in the entire oil zone and small amount in the water zone. Heated air is injected into the formation, the air channeling through the upper part of the water zone and causing an in situ combustion reaction to occur at the oil water contact. Air injection and in situ combustion in the oil water contact heat the oil above by conduction as well as hot gas convection through the oil saturated interval. The injection well is then completed in

the upper portion of the formation and the section in the water zone is closed by cementing, and then steam is injected into the oil saturated interval. 8 claims, 2 figures.

van Os, G. Gasification Process. (to Shell Oil Co.). US Patent 3,972,690. 3 Aug 1976.

A process for the gasification of oil containing finely dispersed solids, e.g., oil from tar sands, by partial combustion in a hollow reactor is described. The gaseous oxidant is introduced into the reactor under flow conditions characterized by a relatively large axial velocity component as compared with the tangential flow component resulting in a relatively long flame.

General Information

Oil Shale. Feb 1978. In Pacific Northwest Laboratory annual report for 1977 to the DOE Assistant Secretary for Environment. Part 4. Physical sciences.

New or improved methods are being developed for organic and inorganic analyses of oil shale and tar sand effluents. Research materials are being prepared for characterization, environmental, and health effects studies.

. Oak Ridge, Tennessee. Inventory of Energy Research and Development: 1973-1975. Volume I, Serial U. Part I. (Oak Ridge National Lab., Tenn. (USA)). Jan 1976.

This inventory provides an overview of the R and D being performed in every aspect of energy exploration, production, distribution, use, and conservation. A brief introduction discusses the aims, history, scope, and design of the inventory. The main body of Volume I, Part I is devoted to bibliographic entries (including abstracts) concerning coal, petroleum, natural gas, and oil shales and tar sands. This inventory expands and updates two earlier inventories of ongoing energy research published in March 1972 and January 1974.

. Oak Ridge, Tennessee. Inventory of Energy Research and Development: 1973-1975. Volume I, Serial U. Part II. (Oak Ridge National Lab., Tenn. (USA)). Jan 1976.

This inventory provides an overview of the R and D being performed in every aspect of energy exploration, production, distribution, use, and conservation. Volume I Part II is devoted to bibliographic entries (including abstracts) concerning oil shales, tar sands, nuclear fuels, solar energy, geothermal energy, hydroelectric power sources, and synthetic fuels. This inventory expands and updates two earlier inventories of ongoing energy research published in March 1972 and January 1974.

. Oak Ridge, Tennessee. Oil Shales and Tar Sands: A Bibliography. (Department of Energy, Oak Ridge, Tenn. (USA). Technical Information Center). Dec 1977. p. 744.

This bibliography contains 5049 citations of foreign and domestic research reports, journal articles, patents, conference proceedings, and books. The citations are arranged in broad subject categories. Four indexes are provided: corporate, author, subject, and report number.

. Washington, D.C. One Hundred and Seventy-third National Meeting of the American Chemical Society. Preprints. Volume 22, No. 2. Washington, DC; American Chemical Society (1977). p. 569.

Papers and abstracts of papers presented at symposia on alkylation, the role of solid-state chemistry in catalysis, thermochemical kinetics and the mechanism of gas phase reactions, and the analytical chemistry of oil shale and tar sands are included. Separate abstracts were prepared for 35 papers.

. Washington, D.C. Symposium on Oil Sand and Oil Shale. American Chemical Society (1977). p. 233.

Papers presented at the conference are concerned with Canada oil sands, chemistry of tar sands, shale oil production, properties of oil shales, properties of asphaltenes, kerogen, and hydrocarbon biodegradation. A separate abstract was prepared for each paper.

Field, J.H. and R.T. Eddinger. 167th National Meeting of the American Chemical Society, Division of Fuel Chemistry, Los Angeles, California, 31 March 1974-5 April 1974. Volume 19, No. 2. Ann Arbor, MI; Xerox University Microfilms (1974).

Abstracts were prepared for three papers presented at the Symposium on Low-sulfur Fuels from Coal: Part II. Abstracts were prepared for twenty-one papers presented at the Symposium on Shale Oil, Tar Sands, and Related Fuel Sources.

Gonzales, S. Some Geological and Political Considerations Regarding Future Production of Domestic Fossil Fuel Energy Resources. (Univ. of Georgia, Athens). Apr 1977.

This paper summarizes the current contribution of domestic crude oil, natural gas, and coal to the production of energy in the United States. It also discusses the economic, political, and societal climate which has emerged in reference to energy since the 1973-74 crude oil embargo. Also considered is the future potential of domestic conventional petroleum resources with an emphasis on measures to promote more aggressive exploration in frontier areas and more application of enhanced recovery. The natural gas situation receives treatment in regard to declining reserves, pricing problems, inadequate foreign supplies and several unusual, potential sources such as coal-seam bleedoff and the artificial fracturing of shales. The potential and problems confronting coal development are also reviewed, and the possible production of synthetic hydrocarbons from coal is discussed. Comments on the status of oil shale and tar sands development conclude the paper. Recommendations for both economic and political policy changes are made throughout the discussion, and include support for various mandatory conservation measures. 34 references.

APPENDIX E
GEOTHERMAL BIBLIOGRAPHY

ECONOMICS
ENVIRONMENTAL IMPACTS
SOCIO-ECONOMIC IMPACTS
SITE REQUIREMENTS
GENERAL INFORMATION

GEOTHERMAL

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- Birsic, Rudolph J. More About Geothermal Steam or The Hottest Energy Prospect Ever. R.g. Birsic, Fullerton, California: October 1976.
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- City of Burbank. Site-Specific Analysis of Hybrid Geothermal/Fossil Power Plants. United States Energy Research and Development Administration, Division of Geothermal Energy: June 1977.
- Eaton, William W. Geothermal Energy. U.S. Energy Research and Development Administration, Washington, D.C.: 1975.
- Friedman, E. and S. Pond. Legal and Institutional Impediments of Geothermal Energy Resource Development: A Bibliography. Mitre Corporation, McClean, Virginia: March 1977.
- Mitora, Stanley L. and Jefferson W. Lester. Geothermal Energy As A Source of Electrical Power: Thermodynamic and Economic Design Criteria. MIT Press; Cambridge, Massachusetts: 1976.
- National Academy of Sciences, The National Research Council. Supporting Paper 4, Geothermal Resources and Technology In the United States (Washington, D.C.: 1979).
- National Science Foundation. Federal Energy Administration, Project Independence Blueprint, Final Task Force Report, Project Independence. November 1974.

The Report of The Geothermal Resource Group Supply and Delivery Panel of the Committee on Nuclear and Alternative Energy Systems, National Research Council. Geothermal Resources and Technology In The United States. National Academy of Sciences, Washington, D.C.: 1979.

U.S. Department of Energy, Division of Geothermal Energy; Department of Energy, Idaho Operations Office; EG & G Idaho, Inc.; University of Utah Research Institute Earth Science Laboratory. Regional Hydrothermal Commercialization Plan. July 14, 1978.

U.S. Department of The Interior, D.E. White and D.L. Williams, Ed. Assessment of Geothermal Resources of The United States--1975. Geological Survey Circular 726.

U.S. Department of the Interior and U.S. Department of Energy. Assessment of Geothermal Resources of the United States--1978, Geological Survey Circular, 790.

U.S. Energy Research and Development Administration. First Annual Report, Geothermal Energy Research, Development & Demonstration Program. Washington, D.C.: April 1977.

U.S. Energy Research and Development Administration, Division of Geothermal Energy. Innovation Versus Monopoly: Geothermal Energy In The West, Final Report, July 1977.

Utah Division of Water Rights, Stanley Green and L. Ward Wagstaff. Time Phased Project Plan For Roosevelt Hot Springs Geothermal Area, July 1979.

Ward, Stanley A. From The Heat of The Earth: The 40th Annual Frederick William Reynolds Lecture. University of Utah Press, Salt Lake City, Utah: 1977.

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Woodward-Clyde Consultants. Plan of Operations, Environmental Baseline Study, Roosevelt Hot Springs Unit, Roosevelt Springs, Utah KGRA: Prepared For Phillips Petroleum Company. Woodward-Clyde Consultants: September 9, 1977.

GEOHERMAL-ECONOMICS

10 MW Geothermal Power Plant Proof-of-Concept Facility. 31 Dec 1974.

Preliminary design work is presented in the areas of (1) thermodynamic characteristics and cycle analysis; (2) facility layout drawings for the 10 MW power plant including the Test Facility; (3) facility process piping and instrumentation diagram and flow diagram; and (4) facility and plant cost estimate.

Resource Utilization. 1976.

Resource utilization studies focused on preliminary conceptual design of commercial-scale electric generation plant, preliminary conceptual design of a test facility. Supporting research elements considered industrial utilization of wellhead and power plant effluent fluids, economic and net energetic analysis of commercial-scale generation units, geothermal water pricing, cooling water availability and general water resources, and fluid disposal technology and economics. Overall objective of these studies was to establish the economic and technical feasibility of utilization and to determine cost and time schedules to implement the recommendations arising out of the research results.

Site-Specific Analysis of Hybrid Geothermal/Fossil Power Plants. (Burbank City Public Service Dept., Calif. (USA)). June 1977. p. 263.

A preliminary economic analysis of a hybrid geothermal/coal power plant was completed for four geothermal resource areas: Roosevelt, Hot Springs, Coso Hot Springs, East Mesa, and Long Valley. A hybrid plant would be economically viable at Roosevelt Hot Springs and somewhat less so at Coso Hot Springs. East Mesa and Long Valley show no economic promise. A well-designed hybrid plant could use geothermal energy for boiler feedwater heating, auxiliary power, auxiliary heating, and cooling water. Construction and operation of a hybrid plant at either Roosevelt Hot Springs or Coso Hot Springs is recommended. A modified version of the Lawrence Berkeley Livermore GEOTHM Program is the major analytical tool used in the analysis. The Intermountain Power Project is the reference all coal-fired plant.

. Economic Study of Low Temperature Geothermal Energy in Lassen and Modoc Counties, California. (California State Civ. of Oil and Gas, Sacramento (USA)). Apr 1977. p. 94.

This report investigates the feasibility of using low cost, low temperature geothermal energy in job-producing industries to increase employment and encourage economic development. The study, encompassing all of Lassen and Modoc Counties, is sites-specific, referencing candidate geothermal applications to known hot wells and springs. The emphasis is placed on economically practical and readily achievable applications from known resources. Land-use planning institutional aspects, geological assessments, technical modeling and socioeconomic impacts are examined.

. Report on the Western Energy Expansion Study. (Bureau of Reclamation, Washington, D.C. (USA)). Feb 1977.

This report contains the results of an assessment by the Bureau of Reclamation of opportunities to respond to urgent needs for additional electrical power and energy in the West which can make an effective contribution to conservation of swindling oil and natural gas resources. The WEES was conducted to identify and evaluate opportunities for increased electrical power and energy generation in the 17 western states which warrant further, more detailed study in the immediate future. Focus of the study was primarily on development of hydroelectric power, including pumped storage, at both new sites and existing facilities. Other opportunities relate to development of electrical energy using solar (direct radiation and wind) and geothermal resources. In addition to develop mental opportunities, several matters of a policy nature are discussed and evaluated.

Anno, G.H.; M.A. Dore, R.L. Grijalon, G.D. Lang, F.J. Thomas. Hybrid Geothermal/Fossil Power Plants: A Site-Specific Analysis. (Pacific--Sierra Research Corp., Santa Monica, CA). (Jun 1978).

Anno, G.H.; M.A. Dore, R.L. Grijalva, G.D. Lang, F.J. Thomas. (Pacific Sierra Research Corp., Santa Monica, Calif. (USA)). Apr 1977. p. 147.

The results of an analytical effort to determine the cost effectiveness of hybrid geothermal/fossil-fuel electrical-power generating stations. The analysis is directed at combining hydrothermal and coal energy in a Rankine steam cycle, for electrical power generation for the city of Burbank, California. This effort develops a methodology for hybrid power-plant cost analysis so that preliminary plant designs can be optimized as a function of specific site conditions and characteristics. It also defines cost-optimized site-specific plant designs for four potential sites: Roosevelt Hot Springs, Utah, Coso Thermal Area, California, East Mesa, California, and Long Valley, California. These optimized designs are compared for the costs, geothermal-resource utilization, and fossil fuel saved. The results indicate that development of geothermal resources to support a hybrid power plant are favorable for at least two of the four sites.

Barr, R.C. Geothermal Energy and Electrical Power Generation. (Earth Power Corp., Tulsa, OK), pp 1937-1941 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ, of California (1976).

The economics of electric power generation by means of fossil fuels and by means of geothermal energy are compared. This paper describes capital and fuel costs in some detail and touches on operating costs. Comparisons for nuclear fuels are not included due to the paucity of satisfactory data; capital costing for nuclear plants also does not lend itself to this comparison. Currently marginal or underdeveloped geothermal sources (such as hot dry rocks or low temperature, highly mineralized water) are not considered. Comparisons are restricted to oil, gas, coal, dry steam, and flashed steam--energy sources with which adequate experience has been gained--and also to binary cycles above a critical temperature. For comparison, the different sources are standardized according to British thermal units (Btu) per commodity unit of the energy source: coal, oil, gas, or geothermal fluid, assuming that the same amount of electricity (1 kWh) is generated for each 10,000 Btu regardless of source, assuming typical plant efficiencies. Data used are from The Geysers, Otake, and Cerro Prieto. Some conversions have been made to adjust the figures to a standard 110-MW generating unit, and to relate all costs to the same late-1973 level. For binary cycle possibilities, only reservoirs whose temperatures exceed 360°F (182°C) are considered commercial in this paper; the amount of hot water consumed per kWh increases markedly at lower temperatures. It is shown that under the conditions assumed, geothermal energy is commercially competitive and can reach profitable levels of operation.

Barrager, S.M.; D.J. Quinn. Economic Analyses of Geothermal Energy Development in California. Volume II. Cost/Benefit Analysis of Government Program Alternatives Regarding Hot Water Geothermal Power. (Stanford Research Inst., Menlo Park, Calif. (USA)). May 1977. p. 127.

Results of a study on the evaluation of potential for geothermal energy development and utilization in California are reported. This is Volume II of the two-volume report. The first four chapters of this volume present a generic analysis of several decisions facing government in the field of hydrothermal energy. The analysis develops a framework for estimating the potential overall benefits of hydrothermal power (detailed in Appendix A). Chapter V contains a site-specific analysis of the decision to fund a demonstration plant at Heber, California. This analysis is performed from the point of view of both the government and the local-electricity consumer. The specific numericals presented are limited to electrical power generated by hot water systems.

Bernard, J.; J.F. Evano. Specification of a Model Applicable to Offshore Geothermal Sources With Nuclear Fracturing. (CEN, Grif-sur-Yvette, France). pp 1554-1558 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Vol. 3. Berkeley, CA; Univ. of California (1976).

In a first step a very simple physical model connecting thermal exchange between rocks and heating fluid is established. This model makes clear two main parameters in the cavity: (1) a characteristic length for getting fluid temperature and inside rock temperature into equilibrium; and (2) a characteristic time for decreasing the enthalpy in the cavity. In a second step, and for a given electrical power plant, a more general investigation, involving the estimation of the distribution of pressure drops in the cavity and the pipes after drilling or redrilling, the strategy of nuclear explosions, and the associated electrical power plant, shows clearly an optimal depth associated with minimal costs. This optimal depth is obviously dependent on parameters such as fracturation quality, geothermal gradient temperature, drilling diameters, and so on, and is practically found between 2500 and 4000 m (7000 and 12,000 ft). In a third step a more complete investigation, including associated costs for drilling, electrical connection between the platform and the shore, safety programs, insurance, interest rates during construction, and power plant operating costs, concludes that so far as fracturation quality is adequate [average range between fractures less than about 5 m (15 ft) and average permeability in the cavity more than 10 millidarcy], offshore geothermal energy is strongly competitive with light-water nuclear energy provided that the geothermal gradient temperature is at least three times greater than normal.

Bloomster, C.H. Economic Analysis of Geothermal Energy. (Batelle Pacific Northwest Labs., Richland, WA). (Jul 1976).

The development of the GEOCOST computer program which combines the technical and economic factors of power generation from geothermal energy into one systematic cost accounting framework is described. The model simulates the cost of geothermal reservoir exploration, development, and operation and the cost of power plant design, construction, and operation. This model showed that fluid temperature, well flow rate, well drilling, and fluid extraction costs are the principal factors that determine the price of geothermal energy.

Bloomster, C.H.; R.L. Engel. Potential National Benefits of Geothermal Electrical Energy Production From Hydrothermal Resources in the West. (Battelle Pacific Northwest Labs., Richland, WA). pp 853-859 of In Eleventh intersociety energy conversion engineering conference. Vol I. New York; (1976).

To evaluate the competitive role of geothermal energy in a predominately nuclear and coal-based electric power economy, a computer simulation of the U.S. power economy was employed. The

simulation optimizes the installation of new generating capacity on a multiregional basis. This study included only the hydrothermal resources in the West. New geothermal capacity in the West, however, has national impact through reducing the demand and the cost of nuclear and fossil fuels. The potential benefits from geothermal energy are estimated at \$2-\$8 billion in reduced electricity costs. Geothermal energy is estimated to achieve 8-20 percent of the electricity generation in the West (9,000-17,000 MWe by 1990). The "most likely scenario" is the lower values in the above ranges. This scenario would save (1) \$11 billion in powerplant capital costs, (2) 32 million separative work units, (3) 64,000 tons (58.2×10^3 tonne) of U_2O_8 , and (4) 700 million barrels ($112 \times 10^6 m^3$) of oil.

Bloomster, C.H.; R.L. Engel. Potential Benefits of Geothermal Electrical Production From Hydrothermal Resources. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Jun 1976. p. 85.

The potential national benefits of geothermal electric energy development from the hydrothermal resources in the West are estimated for several different scenarios. The U.S. electrical economy is simulated by computer using a linear programming optimization technique. Under most of the scenarios, benefits are estimated at \$2 to \$4 billion over the next 50 years on a discounted present value basis and reach 2 to 4 percent of the national total, which will represent 10 to 20 percent of the installed capacity in the West. Installed geothermal capacity in 1990 is estimated to be 9,000 to 17,000 Mw(e). The geothermal capacity should reach 28,000 to 65,000 Mw(e) by year 2015. The "most likely" scenario yields the lower values in the above ranges. Under this scenario geothermal development would save the utility industry \$11 billion in capital costs (undiscounted); 32 million separative work units; 64,000 tons of U_3O_8 ; and 700 million barrels of oil. The most favorable scenario for geothermal energy occurs when fossil fuel prices are projected to increase at 5 percent/year. The benefits of geothermal energy then exceed \$8 billion on a discounted present value basis. Supply curves were developed for hydrothermal resources based on the recent U.S. Geological Survey (USGS) resource assessment, resource characteristics, and projected power conversion technology and costs. Geothermal plants were selected by the optimizing technique to fill a need for "light load" plants. This infers that geothermal plants may be used in the future primarily for load-following purposes.

Bloomster, C.H.; C.A. Knutsen. Analysis of Electricity Production Costs From the Geopressured Geothermal Resource. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Feb 1977. p. 75.

The economics of the geopressured geothermal resource along the northern coast of the Gulf of Mexico is assessed. Geopressured waters are under nearly twice the normal hydrostatic pressure and believed to be saturated with methane. The cost of generating electricity from this resource is estimated based on the description

and conceptual development plans provided by the United States Geological Survey (USGS). Methane content and selling prices are the most important factors affecting the commercial potential of geopressed resources--so it is important that electrical generation be viewed as a by-product of methane production. On the same incremental cost basis, the cost of electricity generated from the geohydraulic energy is potentially competitive with conventional energy sources. This would require development of a small commercial high pressure, hydraulic turbine to extract geohydraulic energy at the wellhead in plants of about 3 MW capacity. Price/quantity relationships are developed for electricity generation from geopressed resources for each of three development plans proposed by USGS. Studies, based on field constructed plants, indicated an optimum power plant size in the range of 20 to 60 MWe, depending on water temperature. However, if standardized thermal conversion power plants could be factory produced in the 6 MWe range competitively with large field constructed plants, then the optimum plant size might be reduced to single wellhead units. Wellhead units would completely eliminate fluid transmission costs, but would probably incur higher costs for heat rejection, power plant operation, and electrical transmission. The upper cost target for competitive wellhead plants would be on the order of \$800/kW in 1975 dollars.

Cohn, P.D.; C.H. Bloomster. Capital Cost Models for Geothermal Power Plants. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Jul 1976. p. 64.

A computer code, titled GEOCOST, has been developed at Battelle, Pacific Northwest Laboratories, to rapidly and systematically calculate the potential costs of geothermal power. A description of the cost models in GEOCOST for the geothermal power plants is given here. Plant cost models include the flashed steam and binary systems. The data sources are described, along with the cost data correlations, resulting equations, and uncertainties. Comparison among GEOCOST plant cost estimates and recent A-E estimates are presented. The models are intended to predict plant costs for second and third generation units, rather than the more expensive first-of-a-kind units.

Comprelli, F.A. Electric Power Generation Using Geothermal Brine Resources for a Proof-of-Concept Facility. (Bechtel Corp., San Francisco, Calif. (USA)). May 1975. p. 175.

This study anticipates a proof-of-concept project to establish the technical, environmental, and economic feasibility of using hot brine resources for electric power production and other industrial applications. The report discusses site selection, energy conversion process evaluation, conceptual design, implementation plan and schedule, and capital cost estimate.

Corrigan, A.E. Estimating the Value of a Geothermal Resource to an Electric Utility. (Portland General Electric Co., OR). Jan 1978.

The decision of an electric utility to accept a particular price for a geothermal resource depends on the "value" placed upon that resource by the utility. This "value" includes a variety of factors, some of which consist of different portions of the cost or price of the resource, but many of which are not directly related to the cost of the resource, and some of which are intangible and thus difficult to quantify. A decision whether or not to invest in a geothermal resource would depend upon all of these factors. The facts considered by a utility in evaluating and comparing alternative sources of electricity are presented and an evaluation of geothermal energy is given with a view toward identifying some of its advantages and disadvantages, and some of the difficulties that would have to be resolved in a pricing arrangement. With full or part ownership of the geothermal resource, the utility has greater control over resource development and availability, but incurs greater risk.

Dolan, W.M. Considerations for the Pricing of Geothermal Energy. (AMAX Exploration, Inc., Denver). Jan 1978.

It is suggested that the price of geothermal energy be pegged to a stable resource, such as coal, in order to allow for changes in generating efficiency over the life of the "fuel" contract. Provisions for reduced or improved performances, such as changes in fluid enthalpy or turbine efficiency, would be added to allow the producer and the utility to share in the resultant change in total electricity cost. A formula to relate such changes relative to the cost of producing electricity by coal was proposed.

Edson, D.A. Introduction to Engineering and Economic Modeling. (VTN Consolidated, Inc., Irvine, CA). 13 Jul 1976.

A modeling concept is described which incorporated both engineering and socio-economic impact modeling elements. The technique suggested is designed to serve as a practical tool for use by local decision makers in evaluating geothermal options. Two hypothetical examples are included to confirm the validity of the model.

Eisenstat, S.M. Geothermal Exploration and Development in the United States: a Tax Analysis Under the Internal Revenue Code. (Eisenstat and Gottesman, P.C., Attorneys at Law, New York), pp 2369-2372 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

Hundreds of millions of dollars are invested annually by the private sector to explore and develop oil and gas properties in the U.S. The risk of such investments is reduced by the tax benefits of such activities. A significant portion of the cost of drilling and completing the well is deductible from the ordinary income of the investor; and if production is established, it is subject to depletion (that is, part of the income is tax free). Geothermal

exploration and development should receive comparable treatment. The Reich and Rowan cases, the only two reported cases relating to geothermal exploration, found that the same favorable tax consequences which result from oil and gas exploration applied to geothermal exploration. The U.S. Internal Revenue Service is still challenging the tax treatment of geothermal exploration. Congress has proposed certain changes in the Internal Revenue Code to benefit the geothermal industry, but additional legislation is necessary to clarify the tax treatment. Once the tax treatment of geothermal exploration and development has been conclusively determined, substantial funds could be deployed to develop geothermal properties. The tax benefits would reduce the risk of the exploration and would also significantly improve the economics of such an investment.

Fick, T.R. Comments on Pricing of Geothermal Energy. (Bechtel Corp., San Francisco). Jan 1978.

A study that included the effects on power plant design and busbar electric energy costs of the anticipated decline in geothermal brine temperature of the Heber reservoir was concluded. A two-stage flashed-steam energy conversion process was used, and two operating modes, constant brine flow and constant power output, were considered. Plant net capacities were taken at 50, 100, and 200 MW(e) as multiples of 50 MW(e) units. The "cost of fuel" was estimated as a direct function of the cost of developing and operating the well field, including the cost of drilling more wells as the reservoir cools with time. Any connection between previous less direct costing bases, such as the cost of oil or nuclear fuel, was avoided. Capital costs for the well field and the power plant were estimated by the usual methods. Cost and power plant energy output were both expressed in levelized annual terms, and a plant capacity factor of 85% was assumed. Results emphasize that realistic "cost of fuel" and the effects of reservoir temperature decay are important and should be included in the pricing of geothermal energy.

Goldsmith, K. Economic Aspects of Geothermal Development. (Electrowatt Engineering Services, Ltd., Zurich). pp 2301-2303 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

A geothermal scheme can be considered to comprise three parts--production, transmission, and conversion of heat. The equipment needed for heat conversion can be closely specified and costed once the input and output conditions have been identified. Heat production and transmission costs are much more uncertain. As existing geothermal heat sources become depleted, new wells have to be established and the configuration of the transmission network will often change during the lifetime of the scheme. Once the initial

investment has been made, there will be recurring capital investment for keeping the converting plants supplied with heat; this expenditure flow may be large enough to put the economic value of the whole geothermal development into question. Heat production also usually involves an important pre-investment phase in which considerable sums may be expended for no foreseeable return; such expenditure is usually written off but this is unsound in economic terms. The true economic merit of the scheme should be determined at the outset by evaluating all relevant preinvestment and predictable post-commissioning expenditure in present-worth terms. The development strategy should be formulated accordingly. To keep a geothermal scheme economically viable throughout its lifetime, the recurring investment and the economic merit must be reassessed periodically and compared with alternatives presenting themselves at that time. Such re-examination might show that heat production must be curtailed by restricting further capital expenditure to achieve an acceptable economic return, and this would result in a given scheme's becoming relegated progressively to a lower order of merit.

Goldsmith, M. Engineering Aspects of Geothermal Development With Emphasis on the Imperial Valley of California. (Calif Inst of Technol, Pasadena). (Apr 1978).

This review was prepared in support of a geothermal planning activity of the county of Imperial. Engineering features of potential geothermal development are outlined. Acreage requirements for drilling and powerplants are estimated, as are the costs for wells, fluid transmission pipes, and generating stations. Rough scaling relationships are developed for cost factors as a function of reservoir temperature. Estimates are made for cooling water requirements, and possible sources of cooling water are discussed. Availability and suitability of agricultural wastewater for cooling are emphasized. The utility of geothermal resources for fresh water production in the Imperial Valley is considered.

Greider, B. Status of Economics and Financing of Geothermal Energy Power Production. (Chevron Minerals, San Francisco). pp 2305-2314 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

Steam geothermal fields are economically attractive. The amount of money needed to find, develop, and operate a field is similar to funds needed for other energy development. Investments and operating costs of geothermal plants are similar to those of fossil-fuel plants. Engineering studies indicate that geothermal binary plants will have competitive economics, although none are now operating on a commercial basis. The ability to obtain capital, material, and personnel will influence the growth of geothermal development. Growth will be significant when the electrical companies find this form of energy as useful as nuclear and fossil fuels. The rate of return adjusted for risk must be attractive

to compete with fuel investment opportunities. The price for steam at The Geysers will be 7.4 mill/kWh by 1977. The busbar price will be 10.9 to 11.4 mill/kWh. Nuclear generation for the same market will cost approximately 15.5 mill/kWh. Coal-fueled plants had busbar costs of 14.5 mill.kWh in 1974. Increased plant operating time may offset these higher costs. Developments in Mexico, El Salvador, and the Philippines appear to be commercially attractive. Combinations of government-private agency financing are showing that this is a reasonable method to use in developing countries. Reported prices for electricity produced in such arrangements should be increased by the amount of tax when compared with production in countries that have such tax.

Holt, B.; E.L. Ghormley. Energy Conversion and Economics for Geothermal Power Generation at Heber, California, Valles Caldera, New Mexico, and Raft River, Idaho: Case Studies. Topical Report 2. (HOLT/PROCON, Pasadena, Calif. (USA)). Nov 1976. p. 124.

A portion of the results from a one-year study to assess the feasibility of constructing a 25 to 50 MWe geothermal power plant using low-salinity hydrothermal fluids as the energy source is presented. The objective of this report was to investigate the compatibility of the different power conversion options with real geothermal reservoirs and to analyze the economics of power generation. Nine cases are discussed which were chosen to yield further insight into the effect of reservoir temperature on the choice of conversion technology and power costs. These cases examine flashed steam, binary cycle and hybrid conversion for Raft River, Idaho, Heber, California, and Valles Caldera, New Mexico that have bottom-hole temperatures of approximately 150°C, 180°C and 260°C, respectively. Conceptual layouts of the power conversion processes, cycle analyses and economic analyses are presented. The principal conclusions are: a hydrothermal demonstration plant is technically, environmentally, and economically feasible in the 1980 time frame; the recommended demonstration site is Heber, Imperial Valley, California; binary cycle power conversion technology is recommended; the recommended demonstration plant capacity is approximately 50 MWe; and there are no overriding environmental constraints.

Holt, B.; E.L. Ghormley. Feasibility Study of a Low-Salinity Hydrothermal Demonstration Plant. (Ben Holt Co., Pasadena, CA). Jan 1978.

The feasibility of constructing a 25 MWe to 50 MWe geothermal power plant utilizing a low-salinity hydrothermal fluid as the energy source was assessed. The first phase of the work led to the selection of a recommended site from sixteen possible locations and a recommended process for the demonstration plant. The Heber reservoir in the Imperial Valley of California and the Valles Caldera reservoir in New Mexico were evaluated in detail, and the Heber reservoir was selected. Three energy conversion processes (flash, binary, and hybrid) were evaluated. The binary conversion was selected for use at the Heber plant. During the first phase

of work, several parallel activities were carried out, including geotechnical, environmental, socioeconomic, and energy conversion economics.

Heitz, L.F. Jr. The Potential for Nuclear and Geothermal Power Plant Siting in Idaho as Related to Water Resources. Technical Completion Report., Mar 1974--Mar 1975. (Idaho Univ., Moscow (USA). Water Resources Research Inst.) Mar 1975. p. 113.

The availability of cooling water in the state of Idaho for use in nuclear and geothermal power production and uranium enrichment facilities is discussed. Physical requirements for cooling water and the effects of water quality standards and water rights laws on cooling water supplies are also investigated.

Juul-Dam, T. Economic Analysis of a Geothermal Exploration and Production Venture. (Atlantic Richfield International Div., Los Angeles); Dunlap. H.F. pp 2315-2324 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

A computerized Monte Carlo simulation model has been formulated and used to perform an economic rush analysis of a geothermal energy exploration and production venture. Expected present worths as well as the actual underlying distributions of present worths were computed for a series of cases. A study of the sensitivity of the economics to changes in the most important parameters is included. For the most likely values of the input variables, chance factors, and parameters, the expected present worth at a 12 percent discount rate is \$3.6 million per exploration unit, while the rate of return is 18 percent. The break-even chance factor per play to yield an expected present worth of zero is 5 percent.

Kelly, R.L. Economic Strategies Toward the Federal Sector: Summary. pp 167-168 of In Geothermal: state of the art. Davis, CA; Geothermal Resources Council. (1977).

The Federal Government dominates the geothermal industry, imposing a series of economic risks and opportunities characteristic of government action. Representatives of the industry should learn to assess these risks and opportunities in a realistic manner and to take effective steps in connection with them. Case examples are provided illustrating these processes in both the executive and legislative branches and their potential outcomes.

Kruger, P. Pricing of Geothermal Energy: Workshop Panel Report.
(Stanford Univ., CA). Jan 1978.

The panel convened to review the various philosophies and approaches to the pricing of geothermal energy for the generation of electric power. One approach suggests that the price of energy delivered to a geothermal plant should be dependent on the thermodynamic properties of the fluid as well as such factors as reliability of supply and price of other available fuels. The price could be determined by the net quantity of heat delivered (e.g., in millions of Btu's above some negotiated reference temperature). This method puts the cost of energy to the utility in the same framework as other fuels and encourages the utility to improve its efficiency in terms of the number of geothermal Btu's required per kWh. An alternate concept considered pegging the price of geothermal energy to a stable resource, such as coal, in order to allow for changes in generating efficiency over the life of the "fuel" contract. A third concept, for pricing geothermal fluids, especially for the more technically uncertain hot-water resources, is adaptation of the pricing policy used at The Geysers steam field, in which the return to the supplier is determined by formula of the costs of alternate fuels available to the utility, adjusted for the differences in plant costs. A fourth concept is making the geothermal resource producer responsible for the generation of electricity, in which the price of the electricity at the busbar becomes the subject of the negotiation between supplier and utility. A fifth alternative among these field-plant relationships is for the utility to purchase part or full ownership of the geothermal resource. The possibility of government-regulated pricing is also considered.

Kunze, J.F.; J.F. Whitbeck. Plan for Developing Moderate Temperature/ Low Salinity Geothermal Resources. (Idaho National Engineering Lab., Idaho Falls (USA)). May 1976. p. 91.

The approach to developing moderate temperature (150° to 300°F) geothermal resources so that these can competitively enter the energy market is herein described. The specifics discussed relate to experiments in the Idaho National Engineering Laboratory's program effort. These involve the energy supply and disposal systems, the surface conversion equipment for generating electricity, and supplementary uses of the heat directly for industrial and agricultural applications. The experimental facilities are located the Raft River Valley area of southcentral Idaho, close to the Utah border, and the document describes the purpose and likely economic benefit to result from this experimental program.

Kunze, J.F.; J.F. Whitbeck, R.H. Dart. Economic Generation of Electricity From Moderate Temperature Geothermal Resources. (Idaho National Engineering Lab., Idaho Falls). pp 768-770 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers (1976).

The large energy potential of the medium temperature geothermal resource (approximately 125-170°C) makes it attractive for power production. The lower efficiency inherent with lower source temperatures apriori leads to the conclusion that it will be difficult to show favorable economics. However, there are basic differences in the engineering approaches that can be applied which favor the use of moderate temperatures. These approaches which are being evaluated on the Raft River geothermal resource (approximately 150°C) and the economics of power production from this resource, compared with more conventional thermal power systems, are presented.

Langelueddecke, E.; W. Schauer, W. Tanner. Aspects of the Energy Economy for the Utilization of the Geothermal Potential. (Dornier-System G.m.b.H., Friedrichshafen (Germany, F.R.)). pp 573-597 of In Energiequellen fuer morgen. (1976) (In German).

The economic importance of geothermal energy for the FRG is estimated. This is done by (a) including today's energy supply structure and the development tendencies of the future energy supply in the considerations; (b) evaluating the geothermal potential with regard to energetic points of view; (c) grouping the geothermal energy in the consumers' structure in temporal terms and the potential geothermal energy plants in local terms; and (d) including in the calculations the utilization of saline deposits for heat storage, the primary energy saving and the investment costs. Finally the global economic importance of geothermal energy is briefly discussed.

Langelueddecke, E.; W. Schauer, W. Tanner. Recommendations for Research and Development Policy. (Donier-System G.m.b.H., Friedrichshafen (Germany), F.R.)). pp 598-603 of In Energiequellen fuer morgen. (1976) (In German)

In the FRG geothermal energy is used at the moment in thermal spas only. Short-term stress for R- and D-work should be laid on the fields of exploration and test drillings. In order to be able to compete with the USA and with Japan, systems analysis and methodical preparations are thought advisable. Furthermore it is recommended to continue the LASL-project and after its successful ending, to determine an optimal location for a test fracture in the FRG.

Langelueddecke, E.; W. Schauer, W. Tenner. Systems for the Utilization of Geothermal Energy. (Dornier-System G.m.b.H., Friedrichshafen (Germany), F.R.)). pp 426-572 of In Energiequellen fuer morgen. (1976) (In German)

This part of the report closely deals with the co-efficiency of the components of geothermal utilization systems and with possible forms of utilizing geothermal energy. First a summary of the variety of the possible systems is given. Then the plants existing are described. In a special chapter with the headline 'costs' the costs for existing geothermal plants which were published are listed and cost examinations for planned types of plants are carried out. With the examples of two calculations, the author tries to record the costs of versions of geothermal energy utilization plants for the FRG. The effects of geothermal energy on the environment are going to become a region which will gain more and more importance. This is why ecologic effects are discussed at the end.

Larson, T. Costs of Geothermal Energy Development. Final Report, January 1977. (Univ. of California, Riverside). pp 314-336 of In Geothermal world directory. Reseda, CA; Geothermal World Publications (1977).

Risks and rewards associated with geothermal development are summarized. Various methods for evaluating geothermal energy as an investment are discussed; factors affecting the investors' risk perceptions are described. Factors influencing the different view of risk taken by the public utilities, in contrast to that of private industry, are discussed.

Lombard, G.L.; J.M. Nugent. San Diego Gas and Electric Company's Pioneering Geothermal Test Work in the Imperial Valley of Southern California, USA. (San Diego Gas and Electric Co., CA). pp 2037-2043 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

Geothermal energy from steam and hot brines in the Imperial Valley of Southern California, USA, is as yet untapped, but has the potential for a significant contribution to the energy supply of the region. San Diego Gas and Electric Company is engaged in a field testing and development program for the extraction of this energy. The main problems lie in the high salinity of the brines (average, 225,000 ppm), the entrainment of corrosive solids in the steam, and the significant amount (3 percent by weight) of noncondensable gases in the fluids. A binary-cycle generating system is planned, which will use isobutane as a working fluid and two-stage flashing to extract the geothermal heat. In 1973 and 1974, laboratory and field tests showed some difficulties with scaling in the equipment and in the reinjection system, but these problems have proved to be tractable. During 1975, San Diego Gas and Electric Company has

been building a 10-MW Geothermal Test Facility near Niland, California, at the southern end of the Salton Sea, for the next stage in the developmental work for the extraction of commercial geothermal power from this field.

Ludviksson, V. Multipurpose Uses of Geothermal Energy: Electric Power Generation and Horticultural Production. (Industrial Development Committee, Reykjavik). pp 2229-2236 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

The heating of greenhouses already presents an important use of geothermal energy in Iceland. The heat is usually supplied in the form of hot water at about 100°C. Greenhouse industries at northern latitudes have commonly used the equivalent of 100 kg/m² in a year to provide the necessary heat to maintain production. At far northern latitudes, light becomes a limiting factor in winter production of horticultural products. The steam from high-temperature thermal fields can be used to produce electricity while the residual heat from flashed geothermal water and possibly the condensation can be used for artificial lighting and temperature control for the cultivation of plants. An economic evaluation based on 33.5 hectares of glass houses and a 14-MW steam power plant shows that the cost of heat to the greenhouse complex would be about 2 percent of the total operating cost, while the same energy from an oil or other hydrocarbon source would result in about 35 to 40 percent of the operating cost at correspondingly higher total operating cost. The effectiveness of artificial lighting in maintaining or promoting plant production is a major unknown factor, which greatly depends on the type of light source, its arrangement, and the type of plant species to be produced. Research is being initiated on this subject in Iceland.

Maslan, F.; T.J. Gordon, J. Stover. Technology Forecast of United States Geothermal Energy Resource Development. (Futures Group, Glastonbury, CT). pp 2409-2419 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

This forecast defines the nature of the technology on which this industry depends, the technological impediments which, if uncorrected, might block its growth, the means available to overcome the impediments, and the range of energy production levels which might possibly be expected from this source. A complete relevance tree for geothermal energy technology was first constructed, and was followed by designed interviews with industrial and scientific authorities. The results of these two steps were analyzed in a series of energy system diagrams synthesizing the overall judgments about technologically feasible levels of development, unconstrained by economic and institutional considerations. In the accelerated case, U.S. geothermal electricity capacity results for 1985 are (MWe): vapor, 3500; liquid, 17,000; hot dry rock, 5000; geopressured, 10,000. The results for the year 2000 are: vapor, 10,000;

liquid, 500,000; hot dry rock, 200,000; geopressed, 54,000. After this analysis, we developed an electric utility simulation model of the decision mechanism involved in the choice and construction of new central-station generating capacity. In effect, this system-dynamics model simulated the introduction of geothermal energy into the utility fuel choice for the U.S. The model incorporates economics, construction time, reliability, fuel availability, environmental factors, and technology. These forecasts simulate the real geothermal energy electricity capacity development and their results were as follows: for 1985, normal development 7000 MWe, accelerated development 19,500 MWe; for 2000, normal development 188,000 MWe, accelerated development 249,000 MWe.

McCabe, B.C. Practical Aspects of a Viable Geothermal Energy Program. (Magma Power Co., Los Angeles); Aidlin, J.W.; Falk, H.W. Jr. pp 2045-2047 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

Magma Power Company, which has now drilled more than 200 geothermal wells, pioneered today's U.S. geothermal operations by successfully completing a dry steam well at The Geysers in 1955. After drilling in many other areas, Magma concluded that all additional U.S. fields probably would involve hot brine; consequently it was essential to develop a binary-cycle process of generation. Patents for such a process, named "The Magmamax Power Process", were obtained by Magma in 1973. Magma's experience established that resources and technology are now available so that geothermal energy can make an earlier and more significant contribution to the U.S. goal of energy independence than any other prospect. Unfortunately, bureaucratic obstacles have unreasonable escalated costs and caused delays running into years. Magma proposes the following program to expedite production of electricity from geothermal sources: (1) erection and operation of at least one 10-MW and one 50-MW binary cycle plant (Magma is currently engineering such plants for construction); (2) simplified government regulations and environmental controls, both the concern of one agency, accompanied by favorable tax treatment; (3) prompt issuance of leases on federal lands in accord with the Congressional intent contained in the Leasing Act of 1970, and immediate implementation of the loan guarantee provisions contained in the Geothermal Energy Act of 1974; and (4) concentration of field efforts on drilling, pumping, and testing to prove the existence of viable fields, and of research on binary-cycle plant operation problems, all without illogical duplication. Acceleration of any program requires the cooperation, heretofore lacking, between this industry, government, and utility companies.

Mukhopadhyay, A.K. Economic and Engineering Implications of the Project Independence 1985 Geothermal Energy Output Goal and the Associated Sensitivity Analysis. (Jet Propulsion Lab., Pasadena, CA). pp 739-746 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers (1976).

The Project Independence 1985 geothermal output goal, viz., 20,000 megawatts (MW), is combined with the available time-line data for a typical geothermal energy plant in order to establish requirements such as the rate of lease award, exploration, production drilling, and plant construction resource expenditure/supply necessary to meet such an adopted goal. Though the specific time-line used in the study is based on detailed discussions with federal, state and industry representatives, time-lines by their very nature can vary drastically with state and local regulations, the nature of the specific reservoir under development and other factors. Similarly, the exploratory and drilling rig efficiencies and the unit costs associated with the various phases of geothermal development depend on today's framework of technological, environmental and economic constraints. Thus, it is highly imperative to determine the sensitivity of the needed rates of development to various technical, economic and institutional parameters. It is equally significant to investigate the sensitivity with respect to variations of the goal magnitude, the goal rate and the goal date from the nominal values set out in Project Independence. A computer program has been written, so that the results of such a sensitivity analysis can be quickly obtained as printed and plotted output with the least expense.

Olson, G.K.; B. Breindel. Electric Conversion Economics. 13 Jul 1976.

This study provides data to determine the economic feasibility of an electric plant as part of a Thermal Utility System for low to moderate temperature geothermal resources. The equipment and plant costs are correlated to size factors based on existing power plant data or equipment manufacturers' data. Instead of a detailed cost estimate for construction from the drawings and specifications of a completely designed plant, this study uses an approximate cost estimating technique for design optimization based on major plant concepts, gross features of the plant, and the important design variables.

Poli, M. Relevance of Geothermal Energy in Today's Energy Situation. (ELC-Electroconsult, Milan). pp 2339-2341 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ. of California (1976).

Traditional geothermal resources can provide only a small fraction of the world energy demand; nevertheless, geothermal generation, where available, has proved very interesting from the economic point of view and for its independence from fuels. Research is

under way for possible new forms of geothermal generation from geopressured brines and dry rocks which might produce substantial quantities of energy. While it appears convenient to increase the exploitation of available traditional resources, interest is stressed on the aforesaid research for possible new forms of geothermal generation. Comparative cost estimates are given for geothermal and fossil-fuel generating plants.

Ramachandran, G. Economics Analyses of Geothermal Energy Development in California. (Stanford Research Inst., Menlo Park, Calif. (USA)). May 1977. p. 147.

Results of a study on the evaluation of potential for geothermal energy development and utilization in California are reported. Volume I of the two-volume report deals with hydrothermal resource costs and economics in terms of various critical parameters pertaining to specific resource locations in California. The important economic factors that influence the development and growth of hydrothermal resources and the probable costs of a hot-water demonstration power plant are also considered. A set of near-term actions and their estimated impacts on hydrothermal resource economics are also discussed.

Ramachandran, G. Economic Analyses of Geothermal Energy Development in California. (Stanford Research Inst., Menlo Park, CA). pp 251-253 of In Geothermal; state of the art. Davis, CA; Geothermal Resources Council (1977).

The utilization of hydrothermal resources in California for future electricity generation is quite uncertain due to the current technical, economic, environmental, and institutional factors affecting their growth and development. The price of electricity from hydrothermal steam is estimated to be about 20 to 22 mills/kWh as compared to 25 to 40 mills/kWh from competitive source of electricity. The technical and economic feasibility of hot water resources for electricity generation has not been proven commercially in California. For optimistic assumptions regarding economic parameters, the price of electricity from hot water resources in California can vary from 35 to 45 mills/kWh depending on the resource. There is considerable scope for hydrothermal contribution in base load capacity to the year 1995. However, for a significant contribution from hydrothermal energy, a hot water demonstration power plant and tax incentives to the resource producer are required in the near future.

Reitzel, J. Utilization of U.S. Geothermal Resources. Final Report. (TRW Systems and Energy Group, Redondo Beach, Calif. (USA)). Dec 1976. p. 104.

This study is concerned with U.S. geothermal resources, their potential for commercial utilization by electric utilities between now and the year 2000, and their impact on the utility industry. USGS estimates of the resources in identified hydrothermal systems were extrapolated to the undiscovered resources marked by hot springs, and further to the blind resources between hot spring areas within the tectonic belts. The resulting estimate of the total hydrothermal resource to a depth of 10,000 ft. is about 100,000 MWe for 30 years with about one-half in undiscovered blind resources, one-fourth in undiscovered hot spring resources, and one-fourth in identified systems. Water rates and direct capital costs for geothermal power plants were evaluated as functions of resource temperature, together with costs and expected flowrates for geothermal wells. Combining these results with the temperature distribution of identified hydrothermal systems, a current supply curve for geothermal energy was made. This shows an estimated 20,000 MWe for 30 years potentially producible with current technology from identified resources for direct capital costs of \$800/KW or less. The projected supply curve shows an estimated 30,000 to 60,000 MWe for 30 years potentially available at \$800/KW or less, in 1976 dollars, taking account of estimated undiscovered resources and probable technical advances.

Sapre, A.R. Evaluation of Geothermal Energy Potential. Stillwater, OK; Oklahoma State Univ. (1974). p. 156.

The objective of this study is to assess the cost of power generated by using "low grade" geothermal energy existing under a variety of naturally occurring conditions. It is also proposed to study the effect of some design variables and natural surroundings on the cost of power. The "low grade" geothermal energy as defined for this study is the geothermal energy available in the areas where the temperature gradient is between 2°F and 5°F per 100 feet. The assessment of the cost of geothermal power is accomplished via development of a techno-economic model for the total system. The development of the model is divided into two parts. First, a mathematical model of the system is developed and then a compatible economic model is built for the cost evaluation. A set of data is then used to arrive at the cost of geothermal power by using the techno-economic model. Using the techno-economic model of the geothermal power system, the cost of geothermal power is assessed to be between 1.2 cents/KWH and 4.9 cents/KWH. This large variation in cost is due to the change in the selection of the design of the power generation system and also due to the varying natural environment.

Schulte, S.C. Capital Cost Models for Geothermal Power Plants and Fluid Transmission Systems. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Sep 1977. p. 61.

The GEOCOST computer program is a simulation model for evaluating the economics of developing geothermal resources. The model was found to be both an accurate predictor of geothermal power production facility costs and a valid designer of such facilities. GEOCOST first designs a facility using thermodynamic optimization routines and then estimates costs for the selected design using cost models. Costs generated in this manner appear to correspond closely with detailed cost estimates made by industry planning groups. Through the use of this model, geothermal power production costs can be rapidly and accurately estimated for many alternative sites making the evaluation process much simpler yet more meaningful.

Schmitt, R.C. Direct Applications of Geothermal Energy. (Idaho National Engineering Lab., Idaho Falls); Schultz, R.J.; Griffith. J.L.; Brown, W.S. pp 815-821 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers (1976).

The direct application of geothermal energy commenced in the United States in the late 1800's but utilization has developed on a very limited scale. The U.S. Energy Research and Development Administration's Idaho National Engineering Laboratory has engaged in expanding the scope of applications and in stimulating the utilization of the low-to-intermediate temperature hydrothermal resources. The techniques currently being used to stimulate growth of the industry include the proposed Geothermal Loan Guarantee Program, compilations of engineering and economic analyses, resource/utilization surveys, demonstration or field verification unit development, and various technology transfer mechanisms. Geothermal energy can be used for almost any activity requiring large quantities of heat at relatively low temperatures. Several types of demonstration and field verification projects have been initiated by the INEL to illustrate this viability. These project areas are central space heating districts, large building space heating using low temperature resources, industrial food processing, agricultural uses and aquaculture. Information which is provided on these project areas includes process type, location, technical problems and goals, and status and schedules.

Sherwood, P.B.; K.L. Newman. Engineering and Economic Feasibility of Utilizing Geothermal Heat From the Heber Reservoir for Industrial Processing Purposes at Valley Nitrogen Producers Inc., El Centro Agricultural Chemical Plant. Final Report. (WESTEC Services, Inc., San Diego, Calif, (USA)). Sep 1977. p. 200.

The engineering and economic feasibility of utilizing geothermal heat from the Heber KGRA for industrial processing purposes at the Valley Nitrogen Producers, Inc. El Centro, California agricultural chemical plant was investigated. The analysis proceeds through the preliminary economics to determine the restraints imposed by geothermal modification size on internal rates of return, and through the energy utilization evaluation to determine the best method for substituting geothermal energy for existing fossil fuel energy. Finally, several geothermal utilization schemes were analyzed for detailed cost-benefit evaluation. An economically viable plan for implementing geothermal energy in the VNP Plant was identified and the final conclusions and recommendations were made based on these detailed cost-benefit analyses. Costs associated with geothermal energy production and implementation were formulated utilizing a modified Battelle Pacific Northwest Laboratories' "GEOCOST" program.

Simmons, G.M. Economics and Projections for Geothermal Development in the Northwest. (Univ. of Idaho, Moscow). (Dec 1977).

The Northwestern states (Washington, Oregon, Idaho) possess a considerable potential for geothermal development. Since most of the known geothermal sources are of moderate temperature, utilization will be primarily nonelectric. The present status of the region's geothermal development is reviewed, and the long range impact that this energy source might have on the Northwest is assessed.

Towse, D. Economics of Geothermal Heat as an Alternate Fuel. (Univ. of California, Livermore). (Dec 1976).

Geothermal energy can substitute for and compete with other fuels, but until now it has been used only in special situations where it costs much less than alternate fuels. Geothermal heat is expected to be developed where it can: (1) compete with alternate fuels, (2) replace scarce fuels, (3) be more environmentally acceptable, or (4) be especially adapted to local needs. Economic problems in development include the often high capital costs of wells and gathering systems and the long lead-times required for electric generating plants. The large investment and long payout times for large industrial uses adversely affect the economics.

Walter, R.A.; S.W. Wilson. Economic Optimization of Binary Fluid Cycle Power Plant for Geothermal Systems. (Battelle Pacific Northwest Labs., Richland, WA). pp 731-738 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers (1976).

An analytical model called GEOCOST has been constructed and used to study the design, performance and cost of geothermal power plants using the binary fluid cycle. The GEOCOST computer program simulated all the major components of a geothermal system and calculates the cost of energy production by equating the present worth of revenues and expenses including investment return over the economic life of the plant and/or reservoir. The characteristics of the binary fluid cycle power plant are determined for a variety of geothermal resources, working fluids, and cycle types. An optimization technique based upon the maximum use of available energy in the geothermal fluid is generated, and results of this optimization technique are compared with computed cost data for a variety of binary power plants.

GEOTHERMAL-ENVIRONMENTAL IMPACTS

. Environmental Impact Analysis Guidelines. 31 Dec 1974.

The purpose of this Appendix is to provide environmental guidelines for the evaluation of the various candidate geothermal energy conversion concepts and, further, to facilitate the engineering design phase. This is not an environmental impact analysis of the project but rather a review of possible environmental impacts which should be considered as the design is being completed. This will permit implementation of design options to minimize the negative environmental impact and enhance the environmental benefits of the overall project.

. Geothermal Energy, An Environmental and Safety Mini-Overview Survey. (Aerospace Corp., Germantown, Md. (USA). Environment and Energy Conservation Div.). Jul 1976.

A survey is presented in order to determine the technology status, gaps, and needs for research and development programs in the environment and safety areas of this resource. The information, gathered from a survey of geothermal energy development undertaken to provide background for an environment and safety overview program, is summarized. A technology assessment for resource development is presented. The three specific environmental problems identified as most potentially limiting to geothermal development (hydrogen sulfide control, brine disposal, and subsidence), are discussed. Current laws, regulations, and standards applying to geothermal systems are summarized. The elements of the environment, health, and safety program considered to be intrinsically related to the development of geothermal energy systems are discussed. Inter-agency interfaces are touched on briefly.

. Balanced Program Plan. Volume 9; Geothermal Energy. Analysis for Biomedical and Environmental Research. (California Univ., Livermore (USA). Lawrence Livermore Lab.). Sep 1976. p. 56.

Geothermal energy is defined simply as the heat of the earth. It constitutes a substantial resource which can be utilized for the production of electrical energy and other uses, but it has so far not been used extensively in the United States. The goals of the ERDA geothermal energy program include the generation of 6000 MW of electric power and the supply of 0.1 quad/year of thermal power of nonelectric applications by 1985. This would be accomplished by utilizing hydrothermal (steam and hot water) reservoirs. The

long-term goal is to achieve a much greater utilization through the development of advanced technologies for additional resource types such as hot dry rock. The primary environmental concerns are the noncondensable gas emissions, especially hydrogen sulfide; the emissions from cooling towers including salts and dissolved gases; the management of spent geothermal effluents; land subsidence following the extraction of geothermal fluids; stimulation of seismic activity by the subsurface injection of spent geothermal fluids; noise, land and resource use alternatives; and the occurrence of accidents such as well blowouts. A comprehensive program of biomedical and environmental research to investigate and recommend solutions to these concerns is developed. It includes the measurement of source terms, the accumulation of baseline and followup data, the study of local and regional ecosystems, documentation of subsurface effects, cost/risk/benefit analyses of alternate technologies, and an integrated assessment of the health, social and economic effects of geothermal energy development. The overall program is presented as thirteen units with a priority of A, B, or C assigned to each. The total recommended program would cost \$8,300,000 in FY 1977.

. Environmental Development Plant (EDP). Geothermal Energy Systems, 1977. (Department of Energy, Washington, D.C. (USA)). Mar 1978. p. 63.

The Geothermal Energy Systems Environmental Development Plan (EDP) identifies the environmental, health, safety, social, and economic issues which are associated with the development, demonstration, and commercialization of geothermal resources and conversion technology. The EDP also describes the actions and implementation strategy required to resolve the issues identified. These actions may include the initiation of R and D activities, operations monitoring, baseline characterization studies, or activities leading to the development of standards and criteria in concert with other responsible agencies.

. Geothermal Handbook. Geothermal Project, 1976. (Jones and Stokes Associates, Inc., Sacramento, Calif. (USA)). Jun 1976. p. 197.

The geothermal program of Fish and Wildlife Service, U.S. Dept. of Interior, aims to develop ecologically sound practices for the exploration, development, and management of geothermal resources and the identification of the biological consequences of such development so as to minimize adverse effects on fish and wildlife resources. This handbook provides information about the ecological effects of geothermal resource development. Chapters are included on US geothermal resources, geothermal land leasing, procedures for assessing the effects on fish and game, environmental impact of exploratory and field development operations, and wildlife habitat improvement methods for geothermal development.

. A Western Regional Energy Development Study: Primary Environmental Impacts. Volume I. Final Report. (Radian Corp., Austin, Tex. (USA)). 1 Aug 1975. p. 193.

Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming contain coal, oil, natural gas, oil shale, tight gas sands, tar sands, uranium, and geothermal resources. The report examines the primary environmental impacts of 38 energy resource development scenarios: the air and water emissions, solid waste, and land requirements of a plant or process. Projected ground level ambient concentrations of pollutants are compared with federal and state standards. Scenarios include all aspects of extraction, conversion, and transportation to the point of end use.

. Western Energy Resources and the Environment: Geothermal Energy. (Resource Planning Associates, Inc., Cambridge, Mass. (USA)). May 1977. p. 117.

Geothermal energy--from subsurface heat sources created by the underlying geologic configuration of the earth--is addressed, from an environmental research and development perspective. The report covers various geothermal energy systems, which serve as present or potential energy sources. These include hydrothermal convection systems, such as geysers and hot springs, hot igneous systems and conduction dominated systems. Special inserts describe how geothermal resource systems are created and developed.

Andersen, S.O. Environmental Impacts of Geothermal Resource Development on Commercial Agriculture: A Case Study of Land Use Conflict. (Resources Economist, San Francisco). pp 1317-1321 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Vol. 2. Berkeley, CA; Univ. of California (1976).

The environmental impacts from geothermal exploitation are largely limited to the area immediately surrounding the production facilities. This creates the unique situation where private landowners and associated development companies could conceivably bear the full benefits and costs of development with neither adverse nor beneficial implications to the rest of society. This relationship provides the remarkable opportunity to test the contention that when all costs and benefits are "internalized," maximum social gain is achieved. The changes in resource management which occur as landowners become better informed of financial and environmental implications of geothermal development are investigated. This paper reports on the preliminary research. The probable impact of actions of increasingly well-informed landowners who negotiate for higher lease returns and stronger environmental protection is examined. First the environmental implications of geothermal development from the private landowner's perspective are summarized, the probable influence on lease provisions is hypothesized, and some of the corporate and social implications of these actions are explored.

Axtmann, R.C. Chemical Aspects of the Environmental Impact of Geothermal Power. (Princeton Univ., NJ). pp 1323-1327 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Vol. 2. Berkeley, CA; Univ. of California (1976).

Every geothermal installation produces a unique set of chemical effluents, which depend intricately upon the geochemistry and the exploitation history of the hydrothermal reservoir and on the individual plant design. Environmental analyses which compare the impact of one geothermal plant with another or with alternative energy technologies are frequently based on instantaneous pollutant emission rates at full power. This procedure can give results that are deceptive and erroneous. Rather, the total history of the installation should be analyzed--including the initial drilling and pre-operational testing phases, the possible presence of wild bores, and emissions during plant maintenance periods. Few extant chemical analyses of hydrothermal fluids extend to the parts-per-billion range, but recent studies of atmospheric mercury levels near thermal areas argue that extensive monitoring programs for trace elements should be instituted. Reinjection of hydrothermal fluids into the reservoirs would obviate many environmental impacts, but gaps in the knowledge of silica chemistry have militated against routine reinjection at liquid-dominated fields. Knowledge of the mechanism and the kinetic characteristics of silica polymerization is fragmentary and contradictory. The most copious of the noncondensable gas effluents from geothermal plants is carbon dioxide; the most objectionable is hydrogen sulfide, although boron and ammonia have caused deleterious effects. Cost studies indicate that, for at least some installations, hybrid power and chemical plants based on the Claus process could provide economical, even profitable, emission control for hydrogen sulfide.

Banwell, C.J. Geothermal Energy and Its Uses: Technical, Economic, Environmental, and Legal Aspects. (United Nations, New York). pp 2257-2267 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources, Berkeley, CA; Univ. of California (1976).

Among the many so-called "new" sources of energy which have been proposed or tested as replacements for the conventional sources (fossil fuels and hydroelectric), geothermal energy is virtually unique as the only alternative which was already cost-competitive with these established sources before the sharp rise in petroleum prices which occurred in 1973. Taking into account the overall effect of petroleum prices on the fossil fuel market, and of the probable cost of increasing the production of fossil fuels from alternative sources, it appears probable that the cost of electrical energy generated from a typical geothermal field will now be roughly half that from any alternative, including nuclear energy. One effect of this cost margin will undoubtedly be to promote the development of geothermal energy from fields which formerly looked

less promising. At the same time expanding use will lead to improved exploration and development methods which, in turn, will result in reduced costs. For the immediate future, it seems probable that geothermal energy will be more beneficial to certain developing countries than to the industrial world. This is because geothermal energy can be developed economically in relatively small packages, ranging from 10 to 100 MW. In this way, the financial burden of heavy initial capital investment can be avoided, and later growth in demand can be met by plant extensions. For countries with limited indigenous fuel sources, the savings in fuel import costs can also become very significant. Thus, with fuel oil at \$10 per barrel, the annual saving in fuel cost by substituting geothermal power would be over \$7 million for each 50 MW of net capacity.

Bell, R.B. Environmental Considerations. (VTN Corp., Irvine, CA).
13 Jul 1976.

Environmental considerations related to geothermal energy development in the Honey Lake Valley Basin discussed include (1) water resources, (2) air quality, (3) ecological aspects, (4) subsidence and (5) seismicity. The application of best practicable siting, facility design, waste management and environmental monitoring technologies can be utilized to avoid significant impact. Baseline monitoring programs should include geophysical (subsidence, seismic and reservoir rock stress determinations for injection zones), meteorological, water and air quality, and biological-ethological studies especially for waterfowl in sensitive environs.

Case, G.D.; T.A. Bertolli, J.C. Bodington, T.A. Choy, A.V. Nero.
Health Effects and Related Standards for Fossil-Fuel and Geothermal Power Plants. Volume 6 of Health and Safety Impacts of Nuclear, Geothermal, and Fossil-Fuel Electric Generation in California.
(California Univ., Berkeley (USA). Lawrence Berkely Lab.). Jan 1977. p. 440.

This report reviews health effects and related standards for fossil-fuel and geothermal power plants, emphasizing impacts which may occur through emissions into the atmosphere, and treating other impacts briefly. Federal regulations as well as California state and local regulations are reviewed. Emissions are characterized by power plant type, including: coal-fired, oil-fired, gas-fired, combined cycle and advanced fossil-fuel plants, and liquid and vapor geothermal systems. Dispersion and transformation of emissions are treated. The state of knowledge of health effects, based on epidemiological, physiological, and biomedical studies, is reviewed.

Brocksen, R.W. Ecological Analyses and Applications. Nov 1977.

Progress is reported on the following: analysis of ecological impacts of construction and operation of nuclear power plants; fossil energy environmental project; ecological analysis of geothermal energy development; HUD modular integrated utility systems; expansion of uranium enrichment facilities at Portsmouth; environmental standard review plans; environmental assessment of cooling reservoirs; and analysis of fish impingement at power plants in the southeastern United States.

Gudiksen, P.H.; M.C. Axelrod, D.L. Ermak, K.C. Lamson, R. Lange. Methodology for Assessing the Potential Impact on Air Quality Resulting From Geothermal Resource Development in the Imperial Valley. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 17 Oct 1977. p. 17.

Methodology in use in the Imperial Valley for assessing the potential impact on air quality that may result from the development of geothermal resources is discussed. The installation of a network of air quality stations for characterizing the air quality and atmospheric transport properties in the valley prior to development is discussed. Analyses of geothermal fluids for various gases are performed to evaluate the potential emission rates from future geothermal power plants. The principal pollutant of concern is H₂S because of its noxious odor and potential release rate. These estimated source emission rates and the appropriate meteorological measurements are used as input to a three-dimensional, atmospheric transport code to estimate the potential changes in air quality that result from various scenarios for development of geothermal power.

Hartley, R.P. Pollution Control in Geothermal Energy. (Environmental Protection Agency, Cincinnati). pp 607-613 of In Proceedings of the 12th intersociety energy conversion engineering conference. Vol. I. La Grange Park, IL: American Nuclear Society, Inc. (1977).

Pollution problems will occur in geothermal energy development because large volumes of spent geothermal fluid will be released, potentially contaminating the air, surface waters, and ground waters. Waters may be highly saline and contain metals in hazardous concentrations. Noncondensable gases are of greatest concern in air discharges. The principal anticipated liquid disposal method is reinjection to the producing reservoir, for which reliable technologies must be developed. Water treatment for surface discharge could be possible but costly, although minerals recovery might be offsetting in some cases. The principal air pollutant of concern is hydrogen sulfide although such constituents as ammonia, radon, and mercury may also be significant. Considerable development and demonstration is under way for hydrogen sulfide removal. Resource characterization data are not yet sufficient to predict the full range of potential pollution problems, particularly for the widespread and variable liquid-dominated resource.

Jhaveri, A.G. Environmental Noise and Vibration Control at Geothermal Sites. (Acoustech Division of Agrimedics, Inc., Bellevue, WA). pp 1375-1378 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Vo. 2. Berkeley, CA; Univ. of California (1976).

Environmental effects of withdrawing steam from the earth are several. Air pollution, thermal pollution, water pollution, land subsidence, ground-water contamination, and possible earth tremors constitute a formidable array of unanswered environmental questions. The more pressing environmental issues generally relate to local effects. Land use, aesthetics, effect on recreation, damage to resources and wildlife, local physical pollutants, geographic changes, and destruction of wilderness areas are environmental effects that immediately affect people and their surroundings. Such effects must--and generally can--be reduced, made beneficial, or offset by responsible and dedicated utility planning. It suffices to say that geothermal power is not environmentally free. Although the economics of geothermal energy appear to be promising, the environmental hazards seem manifold. The effects and control of excessive noise and ground-borne vibrations within the framework of a comprehensive geothermal Environmental Impact Statement (EIS) is the main objective of this paper.

Keast, D.N. Noise-Control Needs in the Developing Energy Technologies. (Bolt, Beranek, and Newman, Inc., Cambridge, Mass. (USA)). Mar 1978. p. 250.

The noise characteristics of existing energy conversion technologies, e.g., from obtaining and processing fossil fuels to power plants operations, and of developing energy technologies (wind, geothermal sources, solar energy or fusion systems) are discussed in terms of the effects of noise on humans, animals, structures, and equipment and methods for noise control. Regulations for noise control are described. Recommendations are made for further research on noise control and noise effects.

Kroodsma, R.L.; R.B. Craig, S.G. Hildebrand. Ecological Analyses and Applications. Mar 1978.

Progress is reported on the following: assessment of nuclear power plants; ecological analysis of uranium mining, milling, and fuel fabrication; environmental impact statements concerning uranium enrichment facilities; site evaluations for storage of radioactive wastes; ecological analysis of geothermal energy development; enhanced oil recover; environmental monitoring plan for modular integrated utility systems; and fossil energy environmental project.

Rea, K.H.; D.A. Dahl, A.K. Stoker. Ecological Studies. Jul 1977:

Studies were conducted on the ecological consequences of geothermal energy, oils, plutonium uranium radioactive effluents, and trace elements from coal utilization. Studies included vegetative stabilization, measurement of radiation exposures in rodents, measurement of radon-222 flux from inactive uranium mill tailings piles, chemical quality of effluents, and others.

Swanber, C.A. Physical Aspects of Pollution Related to Geothermal Energy Development. (New Mexico State Univ., Las Cruces). pp 1435-1443 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Vo. 2. Berkeley, CA; Univ. of California (1976).

Although geothermal energy is frequently called the "clean" form of energy, environmental problems do exist; and these problems must be defined, their deleterious effects evaluated, and suitable methods for monitoring any adverse effects must be developed, preferably at the earliest possible time so that environmental considerations can be incorporated into the planning of long-range development of the resource. Venting of hot geothermal by-products into surface waters or the atmosphere may result in unacceptable environmental effects, particularly in "blind" or "hidden" geothermal fields which have not been subjected to natural thermal pollution from hot springs and geysers. Temporary holding ponds should be constructed to store geothermal fluids during the drilling and testing phases. Noise pollution can be a problem particularly during the drilling and testing phases of development. Land subsidence is a potential hazard of geothermal development, particularly in low- to moderate-temperature liquid-dominated fields where large quantities of water must be extracted in order to sustain production. ReInjection of the geothermal effluent to stabilize the reservoir pressures or the use of downhole heat exchangers are two of several methods by which land subsidence and thermal pollution can be minimized. Generation of earthquakes as a consequence of injecting fluids into areas of active faulting is well documented and such seismic hazards are particularly acute for water-dominated geothermal fields, many of which owe their existence to geothermal waters ascending along active faults. Development should be preceded by a program of microseismic monitoring in order to establish background seismicity, locate areas unsuitable for reinjection, as well as provide valuable information regarding the nature of the geothermal field.

Spaulding, W.M. Jr. Wildlife Consideration in Geothermal Energy Development. 1975.

The problems involved in the balance between the environmental impact of geothermal energy development on wildlife and the nation's energy needs are discussed in general terms.

Tessmer, R.G. Jr. Input--Output Capital Coefficients for Energy Technologies. (Brookhaven National Lab., Upton, NY. (USA)). Dec 1976. p. 32.

Input-output capital coefficients are presented for five electric and seven non-electric energy technologies. They describe the durable goods and structures purchases (at a 110 sector level of detail) that are necessary to expand productive capacity in each of twelve energy source sectors. Coefficients are defined in terms of 1967 dollar purchases per 10^6 Btu of output from new capacity, and original data sources include Battelle Memorial Institute, the Harvard Economic Research Project, The Mitre Corp., and Bechtel Corp. The twelve energy sectors are coal, crude oil and gas, shale oil, methane from coal, solvent refined coal, refined oil products, pipeline gas, coal combined-cycle electric, fossil electric, LWR electric, HTGR electric, and hydroelectric.

Vanston, J.H.; D.B. Elmer, T.C. Gustavson, C.W. Kreidler, K. Letlow, S.C. Lopreato, M. Meriwether, P. Ramsey, K.E. Rogers, J.K. Williamson. Proceedings of Second Geopressured Geothermal Energy Conference, Austin, Texas, February 23-25, 1976. Volume V. Legal, Institutional, and Environmental. (Texas Univ., Austin (USA). Center for Energy Studies). 1976. p. 415.

Three separate abstracts were prepared for Volume V of the Proceedings of the Conference. Sections are entitled: Legal Issues in the Development of Geopressured--Geothermal Resources of Texas and Louisiana Gulf Coast; The Development of Geothermal Energy in the Gulf Coast; Socio-economic, Demographic, and Political Considerations; and Geothermal Resources of the Texas Gulf Coast--Environmental Concerns arising from the Production and Disposal of Geothermal waters.

Weres, O.; K. Tsao, B. Wood. Resource Technology, and Environment at the Geysers. (California Univ., Berkeley (USA). Lawrence Berkeley Lab.) Jun 1977. p. 348.

A general review, description, and history of geothermal development at the Geysers is presented. Particular emphasis is placed on environmental impacts of development of the area. The discussion is presented under the following chapter titles: Introduction; Energy, Enthalpy and the First Law; Vapor-Producing Geothermal Reservoirs--Review and Models; Geothermal; Entropy and the Second Law; Power Plants--Basics; H₂S Emissions; Hydrogen Sulfide--Possible Health Effects and Odor; Other Emissions; Power Plant Hydrogen Sulfide Abatement; Hot Water Based Geothermal Development; Phytotoxicity of Geothermal Emissions; Appendices; and Bibliography.

Wilson, S.H. Possible Conflict Between the Interests of Tourism and Geothermal Power Development. pp 2457-2466 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ, of California (1976).

The discharges of holes drilled for geothermal prospecting or development may cause, through the lowering of the water table, the decay of local hot-spring activity. So far, the losses in New Zealand have been Geyser Valley, a major tourist attraction at Wairakei, two minor areas there, minor hot springs of Kawerau and Broadlands, with a fortunate escape for Waiotapu, a major attraction. There have also been losses through hydroelectric developments, especially at Orakeikorako, a major tourist attraction, where 75 percent of the hot springs have been flooded. If one defines a "hot spring region" as a locality where hot spring areas of varied attractions can be conveniently visited from one center, then there are only five such regions in the world. Yellowstone National Park is preeminent in the number and size of its geyser basins, but the Kotorua-Toupo region, although poor in geysers, has the advantages of accessibility at all seasons, association with active volcanism, and a greater variety of scenery. Any further losses of hot springs in the region, now with four major tourist attractions, would be serious. The underground reservoirs of hot water may last under exploitation for only 100 years, perhaps until nuclear fusion energy makes them unnecessary. Hence the fact that losses have been compensated by tourist interest in the bore field and the power development, loses its significance, especially as later power developments will not have the same interest. Tourism, even if modified in ways not yet envisaged, can be expected to last as long as the natural springs, perhaps for thousands of years. Serious clashes between tourist interests and power developments seem to need further consideration only in New Zealand.

GEOTHERMAL-AIR QUALITY IMPACTS

Study of Geothermal Prospects in the Western United States. (TRW Systems Group, Redondo Beach, Calif, 1976. p. 133. 20 Aug 1976).

The commercial development potential of 13 underdeveloped geothermal prospects in the Western United States has been examined and the prospects have been ranked in order of relative potential for development on the basis of investment considerations. The following were considered in the ranking: geotechnical and engineering data, energy market accessibility, administrative constraints, and environmental and socio-economic factors. The primary ranking criterion is the unit cost of energy production expected from each prospect. This criterion is obtained principally from expected reservoir temperatures and depths. Secondary criteria are administrative constraints, environmental factors and the quality of the geotechnical data. The Roosevelt, Utah prospect ranks first in development potential followed in order by Beowawe, Nevada; Coso Hot Springs, California; Long Valley, California; and Brady's Hot Springs, Nevada.

Allen, G.W.; H.K. McCluer. Abatement of Hydrogen Sulfide Emissions From the Geysers Geothermal Power Plant. (Pacific Gas and Electric Co., San Ramon, CA). pp 1313-1315 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Vol. 2. Berkeley, CA; Univ. of California (1976).

The hydrogen sulfide (H_2S) emissions abatement program at The Geysers geothermal power plant is summarized, and the actions currently under way to reduce these emissions are described. The Geysers steam averages 223 ppM H_2S by weight which, after passing through the turbines, leaves the power-generating units both through the gas ejector system and by air-stripping in the cooling towers. The hydrogen sulfide dissolved in the cooling water can be controlled by the use of an oxidation catalyst, such as an iron salt, so that it is reacted to sulfur before entering the cooling tower. The H_2S in the low-heat-value ejector offgasses may be burned to sulfur dioxide and scrubbed directly into the circulating water for reinjection into the steam field with the excess condensate. The disposal of the impure sulfur produced, design requirements for retrofitting existing plants, and modified plant operating procedures are also described. Discussions of future research aimed at improved H_2S abatement systems are included.

Rosen, L.C. Review of Air Quality Modeling Techniques. Volume 8.
(California Univ., Berkeley (USA). Lawrence Berkeley Lab.) Jan
1977. p. 47.

Air transport and diffusion models which are applicable to the assessment of the environmental effects of nuclear, geothermal, and fossil-fuel electric generation are reviewed. The general classification of models and model inputs are discussed. A detailed examination of the statistical, Gaussian plume, Gaussian puff, one-box and species-conservation-of-mass models is given. Representative models are discussed with attention given to the assumptions, input data requirement, advantages, disadvantages and applicability of each.

Semrau, K.T. Control of Hydrogen Sulfide From Geothermal Power Production. (Stanford Research Inst., Menlo Park, CA). 1976.

The "best available control technology" in regard to geothermal power systems is reviewed. Various methods for the removal of H₂S from the noncondensable gas streams, as well as the condensate are discussed.

Tomany, J.P. Air Pollution Emissions Control for Geothermal Energy Plants. (VTN Consolidated, Inc., Irvine, CA). pp 295-297 of In Geothermal: state of the art. Davis, CA; Geothermal Resources Council (1977).

Geothermal energy conversion plants comprise resource drilling, a fluid transmission network and the power generation plant. The extracted geothermal resource may be either water- or steam-dominated, with varying degrees of air pollution impacts associated with each of the operations for each fluid system. The major potential air-borne pollutants emitted by a geothermal energy extraction complex are particulates and hydrogen sulfide (H₂S). The latter steam-dominated resources are prevalent. A number of particulate and hydrogen sulfide emission control systems are currently being developed to ensure compliance with relevant air pollution regulations and standards in The Geysers region. A number of the more viable systems may soon be ready for commercial application.

GEOTHERMAL-WATER QUALITY IMPACTS

Hansen, D.C. Water Conflicts From the Viewpoint of a Regulator. pp 9p, Paper 7 of In Geothermal Resources Development Institute conference. Boulder, CO; Rocky Mountain Mineral Law Foundation (1977).

Maps are given showing known geothermal resource areas and areas that are prospectively valuable in the western states. From the viewpoint of a regulator, the biggest hurdle for geothermal development to overcome is the large quantity of water that will be consumptively evaporated into the atmosphere in the generation of electricity. Current estimates for the amount of water consumed is 48 acre-feet/year/MW. Water rights need to be protected but, on the other hand, geothermal development cannot be based on a presumption of interference.

Layton, D.W. Water Supply Dilemmas of Geothermal Development in the Imperial Valley of California. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 15 Sep 1976. p. 21.

There are four known geothermal resource areas in the Imperial Valley that have a combined potential of over 4,000 megawatts of electrical energy for 25 years. The water resources available to support geothermal energy development are imported Colorado River water, agricultural waste waters, Salton Sea water, and ground water. In addition, geothermal power plants can produce their own cooling water requirements of geothermal facilities along with a series of real and potential constraints may cause water supply dilemmas involving both the acquiring and use of cooling water. Important constraints are institutional policies, water supply costs, technical problems, and impacts upon the Salton Sea. These constraints and related dilemmas are examined in light of relevant information on the valley's water resources, geothermal resources and energy technologies, cooling water requirements, and water supply options.

GEOHERMAL - SOCIO-ECONOMIC IMPACTS

Direct Heat Applications of Geothermal Energy in The Geysers/Clear Lake Region. Volume I. Geotechnical Assessment, Agribusiness Applications, Socioeconomic Assessment, Engineering Assessment. Final Report. (Geonomics, Inc., Berkeley, Calif, (USA)). Aug 1976. p. 256.

Discussion is presented under the following section headings: background and some technical characteristics of geothermal resources; geology and geohydrology, geophysics, and conclusions regarding availability of geothermal energy for nonelectric uses; agricultural assessment of Lake County, site assessment for potential agricultural development, analysis of potential agricultural applications, special application of low cost geothermal energy to algae harvesting, development of an integrated agribusiness, geothermal complex in Lake County, analysis of individual enterprises, and recommendations for subsequent work; demographic characteristics, economic condition and perspective of Lake County, economic impact of geothermal in Lake County, social and economic factors related to geothermal resource development, socioeconomic impact of nonelectric uses of geothermal energy, and identification of direct heat applications of geothermal energy for Lake County based on selected interviews; cost estimate procedure, example, justification of procedure, and typical costs and conclusions; and recommended prefeasibility and feasibility studies related to construction of facilities for nonelectric applications of geothermal resource utilization.

Cady, D.P.; J.C. Jeskey. Definition of an Institutional Structure. 13 Jul 1976.

The rationale and procedures used in selecting and structuring the candidate SGEP administrative vehicle are described. The institutional structure is bounded not only by legal considerations but is more stringently constrained by fundamental needs of the community. Criteria and considerations for the planning of local ordinances have also been included.

Engelbert, E.A. Discussion of "Interdisciplinary Approach to Geothermal Development," by M. K. Fulcher. (Univ. of California, Los Angeles). pp 209-219 of An Interdisciplinary Analysis of Water Resource Systems. New York; American Society of Civil Engineers (1975).

A discussion is presented on the need for socio-economic analysis concerning policies that should govern geothermal resources development in southeastern California before major development gets under way. Engelbert recommends this approach over that of Fulcher, who concentrates on socio-economic analysis of what the after-consequences may be. According to Engelbert, it is the policies which will govern the commencement of large-scale geothermal development which will in turn greatly determine the subsequently ensuing undesirable socio-economic impacts. Considered herein are some of the major policy issues which urgently need to be pursued and answered. Included are legal considerations, development policies, energy policy, water policy, and regional planning and coordination. The author is in full agreement with Fulcher's statement, "The insights from all disciplines are essential for most effective development and for a realistic and comprehensive perspective of alternatives." Most critical for public policy now, believes Engelbert, is sorting out priorities and options before major development begins so that the nation will derive optimum benefits from this resource.

Gardner, R.J.; W.H. Whitney. Socio-Economic Model. (Williams-Kuebel Beck and Associates, Inc., Marina del Rey, CA). 13 Jul 1976.

The Socio-Economic Model has been designed to enable the user communities to project the community-wide impacts of proposed industrial enterprises related to the utilization of the geothermal resource. The Model has been prepared in a handbook format to facilitate its use.

Goldman, G.; D. Strong. Governmental Costs and Revenues Associated With Geothermal Energy Development in Imperial County. Special Publication 3241. (California Univ., Berkeley (USA). Cooperative Extension Service). Oct 1977. p. 80.

This study estimates the cost and revenue impacts to local governments of three geothermal energy growth scenarios in Imperial County. The level of geothermal energy potential for the three development scenarios tested is 2,000, 4,000 and 8,000 MW--enough power to serve 270,000 to 1,000,000 people. The government agencies involved do not expect any substantial additional capital costs due to geothermal energy development; therefore, average costing techniques have been used for projecting public service costs and government revenues. The analysis of the three growth scenarios tested indicates that country population would increase by 3%, 7% and 19% and assessed values would increase by 20%, 60% and 165% for Alternatives No. 1, No. 2 and No. 3 respectively. Direct and indirect effects would increase new jobs in the country by

1,000, 3,000 and 8,000. Government revenues would tend to exceed public service costs for county and school districts, while city costs would tend to exceed revenues. In each of the alternatives, if county, cities and school districts are grouped together, the revenues exceed costs by an estimated \$1,600 per additional person either directly or indirectly related to geothermal energy development in the operational stages. In the tenth year of development, while facilities are still being explored, developed and constructed, the revenues would exceed costs by an approximate \$1,000 per additional person for each alternative. School districts with geothermal plants in their boundaries would be required by legislation SB 90 to reduce their tax rates by 15% to 87%, depending on the level of energy development. Revenue limits and school taxing methods will be affected by the Serrano-Priest decision and by new school legislation in process.

Larson T. Costs of Geothermal Development. (Univ. of California, Riverside). (Jan 1977).

Anticipated costs of geothermal power development in the imperial Valley are presented. Both optimistic and pessimistic projections of the capital and operating expenses necessary to develop and maintain a 200-MW geothermal field and power plant for 20 to 30 years are presented. Included is a discussion of exploration costs, capital costs, operating costs, and the many assumptions made in making the projections. Data on the flow of funds over the periods of exploration, field and plant development, and the operating life of the field are tabulated.

Maslan, F.; T.J. Gordon, L. Deitch. Economic and Social Aspects of Geothermal Energy Resource Development. (Futures Group, Glastonbury, CT). pp 2325-2331 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Berkeley, CA; Univ, of California (1976).

Development of geothermal energy in the United States will be paced by a number of socio-economic impediments as well as by technological problems. The issues are associated with providing a financially viable base for exploration and development, assuring a market for geothermal steam or hot water, and accomplishing the required research and development in a timely manner. Geothermal development will change the electric utility fuel mix by substituting for nuclear and coal generating plants. Businesses involved in the exploitation of geothermal energy and businesses which can uniquely utilize geothermal resources will be stimulated. Macroeconomic factors will be affected because development of geothermal energy seems likely to furnish 5% to 10% of the total U.S. electricity demand by the year 2000. This level of development will stimulate construction of a national electrical grid. Acceleration of geothermal energy development requires changes in certain marketing, financial, and other institutional arrangements. Currently, government regulations overlap and cause delays. Another major problem area is the securing of adequate financing for timely

development. The impacts on housing and cities stem from industrialization resulting from the development of the geothermal resource itself and from businesses which can utilize the heat and mineral content of the geothermal fluids. Economic and urban planning benefits will derive from geothermal space and process heat. Geothermal energy will affect international trade relations; foreign technological aid and geothermal markets can be expected to develop as early as the late 1970's.

Ruzicka, W. Psychosocial Ecology in the Development of Resources.
Psychosocial Ecology in Geothermal Development. (Psychological
Health Services Center, Palo Alto, CA). 1976.

Details of a proposed model study on human ecological conditions are given. This model would not only serve as a basis of study of ways of lessening adverse effects on the human environment, but would identify, explore, and promote the secondary, people-oriented uses of geothermal development as well as the primary, commercial uses.

GEOTHERMAL-SITE REQUIREMENTS

. Conceptual Design of Commercial 50 MWe(net) Geothermal Power Plants at Heber and Niland, California. Part I. Heber. Oct 1976.

The basic objectives, assumptions and results for the conceptual design of the geothermal power plant at Heber, California, are presented. The analytical and design methods used in the study, primary data and information developed, recommended research and development projects and a summary of plant capital cost and construction schedule estimates are included. A two-stage flashed-steam energy conversion process was selected for use at the power plant.

. Experimental Geothermal Research Facilities Study (phase 0). Volume 2. (TRW Systems Group, Redondo Beach, Calif. (USA)). 31 Dec 1974.

The basic criteria for site selection for the geothermal conversion experimental facility are outlines, and an evaluation of the East Mesa area in the Imperial Valley of California is given. Data on the East Mesa geothermal field are given including thermal, gravity, magnetic, seismic, and electrical data. Reservoir geologic data and data on the chemical composition of the reservoir fluid, obtained primarily from well logs, are given. Also, the possibility of subsidence is considered.

. Definition of Requirements for Geothermal Power Conversion System Studies. (Bechtel Corp., San Francisco, Calif. (USA)). 30 Jun 1977. p. 45.

Candidate power conversion systems and criteria for comparing these systems are listed. The elements of each conceptual design and standard approaches to equipment design are described. The methods used to calculate heat and mass balances and the data used in the calculations are described. The method used in developing the economics of each system is described and factors such as construction wage rates, common to all systems, are included. Standard methods for developing the conceptual designs and corresponding economics are defined so that the results of each system study can be readily compared to those of the others. The candidate conversion systems are; multistage flash/binary; two-stage flash with scrubbing; total flow; multistage flash/direct contact (Bechtel patented process); four-stage flash/binary; binary with direct contact heat exchangers; hybrid-flash/binary; hybrid-flash/total flow; and flash/dual cycle binary.

Brown, B.; S. Oliva, B. Beutenmuller, S. Eiter, E. Diamond, V. Greene. California Energy Commission Biennial Report. Power Plant Siting Report: Facility Siting Division. (California Energy Resources Conservation and Development Commission, Sacramento (USA)). Nov 1976. p. 43.

Section 25309(d) of the California Public Resources Code requires that the Commission prepare a list, to include maps, of existing electrical power generating sites. This list and a map of the sites are included. Both items have been prepared from a data file maintained on each of the generating plants. For example, the map was generated by computer using longitude and latitude coordinates from the file. The sources used in the compilation of this file include Federal Power Commission Annual Reports, Public Utilities Commission G.O. 131 reports, Utility Submittals to the California Energy Commission, U.S. Geological Survey Data, and various California State Agencies. The information presented represents the most current information to date but will require periodic updating and revisions. The information is believed reliable and accurate; however, no warranty to that effect is expressed or implied. The material contained within the file is provided for informational purposes only.

Biagini, F.V. Geysers Geothermal Development. (Pacific Gas and Electric Co., San Francisco). (1977).

Ermak, D.L. Scenario for Geothermal Electric Power Development in Imperial Valley. (Univ. of Calif, Lawrence Livermore Lab). (Apr 1978).

The growth of geothermal electric power operations in Imperial Valley, California is projected over the next 40 years. With commercial power forecast to become available in the 1980s, the scenario considers three subsequent growth rates of 40, 100 and 250 megawatts (MW) per year. These growth rates, along with estimates of the total resource size, result in a maximum level of electric power production ranging from 1000 to 8000 MW to be attained in the 2010 to 2020 time period. Power plant siting constraints are developed and used to make siting patterns for the 400 through the 8000 MW level of power production. Two geothermal technologies are included in the scenario: flashed steam systems which can produce their own cooling water from the geothermal steam condensate and which emit noncondensable gases to the atmosphere, and high pressure, confined flow systems which inject all the geothermal fluid back into the ground. An analysis of the scenario is made with regard to well drilling and power plant construction rates, land use, cooling water requirements, and hydrogen sulfide emissions.

Goldsmith, M. Engineering Aspects of Geothermal Development in the Imperial Valley. (California Inst. of Tech., Pasadena (USA). Environmental Quality Lab.). Dec 1976. p. 54.

In order to provide background for introduction of a Geothermal Element into the General Plan of the County of Imperial, California, studies were conducted on resource evaluation, engineering development, environmental impact, economics, regulation, and so forth. This document is a collection of reviews of engineering matters pertinent to the County's plan. Briefly, the contents include discussions of drilling practice, costs, and land requirements. Brief notes on reinjection and on fluid transmission follow. The section on power plants attempts to give scaling relationships for land area, costs, and performance, according to size and reservoir temperature. The problem of cooling power plants is important, particularly in an arid agricultural area. Cooling requirements, water availability, and water suitability are discussed in turn. The question of the interactions of the hydrologic cycle, withdrawals for cooling, and the Salton Sea is covered in a separate EQL document. Finally, there are sections devoted to nonelectrical uses for the geothermal resources, including production of fresh water and chemicals. The direct uses for geothermal heat are not included.

Holt, B.; E.L. Ghormley. Preliminary Design Manual for a Geothermal Demonstration Plant at Heber, California. (HOLT/PROCON, Pasadena, Calif. (USA)). Feb 1978. p. 149.

A preliminary design of a 50 MWe Geothermal Demonstration Plant for Heber, California is presented. A site description, design basis, process design, trade-off studies to optimize plant operations, and an economic analysis of the plant are included. The plant design provides flow diagrams and equipment specifications for the energy conversion system, the cooling water system, the plant and instrument air system, the flare system, the firewater system, the electrical system, the piping system, instruments and controls, and buildings and structures.

Hovland, H.J.; M.G. Storchillo. Siting of a Geothermal Power Plant: Impact of Geotechnical Engineering on Site Utilization and Seismic Design. (Pacific Gas and Electric Co., San Francisco). pp 1B3.1-1B3.8 of Energy resources and excavation technology. Wang, F.D.; Clark, G.B. (eds.). Golden, CO; Colorado School of Mines (1977).

The siting of Geysers Unit 14, a geothermal power unit in the Geysers Known Geothermal Resources Area (KGRA), California, is discussed. Regional and local geology, historic seismicity, existing power plants, and the operation of a typical geothermal power plant in The Geysers area are described. The site selection process is multidisciplinary, involving various criteria associated with steam availability, environmental, operational, and geotechnical considerations. In the siting of this particular power plant, geotechnical engineering, geology, and seismicity were particularly important. The San Andreas Fault, 50 km to the

southwest, is the dominant feature of the regional seismicity. A shear zone or fault crosses the site. The site is bounded by a landslide, steep slopes, and a wooded ravine. Utilization of the limited space became a major challenge. Facilities were placed on both sides of the shear zone, and connecting elements crossing the shear zone were designed to be flexible. Earthwork operations were so planned that the wooded ravine and an adjacent stream would be left undisturbed, preserving the natural environment. Retaining walls and a cantilever structure were required to accommodate steep hills, slope stability, and the active landslide. How a critical facility can be designed on a very difficult site by appropriately weighing the geologic hazards involved and by accepting reasonable risks in future plant operation is shown.

Nero, A.V.; M.S. Quinby-Hunt. Health and Safety Impacts of Nuclear, Geothermal, and Fossil-Fuel Electric Generation in California. Volume 9. Methodologies for Review of the Health and Safety Aspects of Proposed Nuclear, Geothermal, and Fossil-Fuel Sites and Facilities. (California Univ., Berkeley (USA). Lawrence Berkeley Lab.) Jan 1977. p. 162.

This report sets forth methodologies for review of the health and safety aspects of proposed nuclear, geothermal, and fossil-fuel sites and facilities for electric power generation. The review is divided into a Notice of Intention process and an Application of Certification process in accordance with the structure to be used by the California Energy Resources Conservation and Development Commission, the first emphasizing site-specific considerations, the second examining the detailed facility design as well. The Notice of Intention review is divided into three possible stages: an examination of emissions and site characteristics, a basic impact analysis, and an assessment of public impacts. The Application for Certification review is divided into five possible stages: a review of the Notice of Intention treatment, review of the emission control equipment, review of the safety design, review of the general facility design, and an overall assessment of site and facility acceptability.

Ridley, A.P.; C.L. Taylor. Earthquake-Related Geologic and Seismic Safety of Geothermal Developments. (Woodward-Clyde Consultants, Oakland, CA). pp 1411-1415 of In Proceedings of the second United Nations symposium on the development and use of geothermal resources. Vol. 2. Berkeley, CA; Univ. of California (1976).

The locations of known geothermal resource areas in the world coincide with zones of high seismicity and active tectonism. Because of the potential for environmental damage, loss of investments, and social and economic disruption resulting from failure of geothermal developments due to earthquake-related geologic and seismic hazards, it is essential that such hazards be evaluated and considered during site selection and facilities design. Earthquake-related geologic and seismic hazards to be considered are

surface fault rupture, earthquake ground shaking, ground failure, tsunamis, seiches, and seismically-induced flooding. Regional evaluations of these hazards include studies of regional geology, regional tectonics and historical seismicity with aerial reconnaissance, aerial photo-interpretation, and remote sensing techniques. Specific studies for detailed siting evaluations should include geologic mapping, exploratory borings, exploratory trenching, geophysical surveys, laboratory testing of site materials, and engineering analysis of laboratory and field data. Such studies can produce valuable estimates of the maximum credible earthquake, the potential for surface fault rupture, ground failure (including liquefaction, landsliding, lurching differential compaction, and lateral spreading), tsunamis, seiches, and seismically induced flooding. The results of these studies can then be considered in the location and design of geothermal facilities.

GEOTHERMAL-GENERAL INFORMATION

. Retrieval of Geoscience Information. Proceedings of the Tenth Annual Meeting of the Geoscience Information Society Held October 21st, 1975, in Salt Lake City, Utah. Falls Church, VA; Geoscience Information Society (1976). p. 197.

Symposium I, The Location and Retrieval of Energy Resource Information, consists of eight papers, namely: Data Tagging in Information-Accessing Services Containing Energy-Related Data; Considerations for the Design of a National Information Center for Renewable Energy Sources; Experimental Design of Information Systems for Crises Management; Development of a Geothermal Thesaurus; Technical Information Programs of the Federal Energy Administration; National Geothermal Information Resource; Data Base for Surface Mining and Land Reclamation; and The ERDA Technical Information Program. Two papers cited but not given at the conference were Environmental Sciences Data for Energy R and D (Fossil Fuels) and Development of a Computer-Based Energy Integrated Vocabulary. At Symposium II, Data Retrieval for the Student Research, and the Environmentalist, seven papers are included, namely: Teaching Library and Literature Search Strategy to Geology Students; Water Resources Literature Cited in Wisconsin Department of Natural Resources Publications (1964-1973); GeoRef Developments (machine readable bibliographic data base for geology); The Awareness of Relevant Water Resources Literature; Environmental Policy Making and Information; A Comparison of Journal Articles in Environmental and Laboratory Science; and The MINT System; A Scheme for Organizing a Small Map Collection.

. Geothermal Energy Prospects for the Next 50 Years. (Electric Power Research Inst., Palo Alto, Calif. (USA)). Feb 1978. p. 92.

Three facets of geothermal energy--resource base, electric power potential, and potential nonelectric uses--are considered, using information derived from three sources: (1) analytic computations based on gross geologic and geophysical features of the earth's crust, (2) the literature, and (3) a worldwide questionnaire. Discussion is presented under the following section headings: geothermal resources; electric energy conversion; nonelectric uses; recent international developments; environmental considerations, and bibliography.

Energy Technologies for the West: Geothermal Energy From the Earth. Workshop Held in San Francisco, California, 21 September 1976. (Energy Research and Development Administration, Washington, D.C. (USA)). 1976. p. 68.

Dr. John W. Shupe, University of Hawaii, the first of seven speakers, reviewed geothermal sources in Hawaii by means of a slide presentation. Prof. Hamilton Hess, University of San Francisco, dealt philosophically with geothermal energy, considered an "exotic alternative, or at best, a marginal energy source." Robert G. Lacy, San Diego Gas and Electric Co., discussed geothermal development in the Imperial Valley. Dr. Tsvi Meiday, Geonomics, Inc., discussed the size of the geothermal resource and how far away full utilization of the resource is. Donald Finn, Geothermal Energy Institute, presented slides of geothermal sources ranging from areas in New England to the geysers in the western U.S.; he also touched on some legal aspects about leasing areas for geothermal development. John Aldridge, Nevada Power Co., discussed further the legal impediments to geothermal development, with comments especially on the Geothermal Steam Act of 1970. Jim Breese, Acting Director, Division of Geothermal Development, ERDA commented further on ERDA's program. The questions asked and answered in the panel discussion that followed are presented.

Geothermal Resources: Exploration and Exploitation. A bibliography. (Energy Research and Development Administration, Oak Ridge, Tenn. (USA). Technical Information Center). Jul 1976. p. 636.

This comprehensive bibliography contains 5476 citations of foreign and domestic research reports, journal articles, patents, conference proceedings, and books concerned with the exploration and exploitation of geothermal resources. The coverage dates back as far as useful references could be obtained and extends through June 1976. References are arranged in broad subject categories and are made up of complete bibliographic citations. These are followed by a listing of subject descriptors used to describe the subject content of each reference. Four indexes are included: Corporate, Personal Author, Subject, and Report Number. Also included is a list of journals from which articles were selected.

Project Independence Blueprint. Task Force Report. Geothermal Energy. Final Report. (Federal Energy Administration, Washington, D.C. (USA)). Nov 1974. p. 125.

This report of the Interagency Geothermal Task Force analyzes the potential production capabilities of the geothermal industry and the resources necessary to achieve these levels of production. The study covers four areas: resources exploration and assessment; environmental, legal and institutional research; resource utilization projects; and advanced research and technology efforts. The analysis considers constraints inhibiting rapid and widespread utilization of geothermal energy, such as technological, environmental, regulatory and legal, resource and institutional constraints and discusses accelerated supply projections.

Proceedings of the Second United Nations Symposium on the Development and use of Geothermal Resources Held at San Francisco, California, May 20--29, 1975. Volume 1. Berkeley, CA; University of California (1976). p. 844.

The 299 papers in the Proceedings are presented in three volumes and are divided into twelve sections, each section dealing with a different aspect of geothermal energy. Rapporturs' summaries of the contents of each section are grouped together in Vol. 1 of the Proceedings; a separate abstract was prepared for each summary. Volume 1 also contains ninety-eight papers under the following section headings: present status of resources development; geology, hydrology, and geothermal systems; and geochemical techniques in exploration. Separate abstracts were prepared for ninety-seven papers. One paper was previously abstracted for ERA and appeared as CONF-75025--17.

Austin, W.H. Jr. Geothermal Power Emerging as an Alternate Energy Source. (Oct 1977).

Recent court decisions on both the State and Federal level in the USA have indicated that geothermal energy is to be considered a mineral resource rather than a water resource. The decisions were based on the fact that the commodity sought is heat, not the transfer medium. This should remove at least one barrier to development. Geothermal resource development was pioneered in Italy in 1904 and the present Italian capacity of 435 MW powers most of the State Railway system. Production and development in the USA is described, including recent steam production in Hawaii. Development in the USA is largely hampered by regulatory constraints. Japan's approach is aggressive; plans call for 50 GW production by the year 2000. Iceland and Mexico both have an impressive resource base, and exploration continues in Central and South America, the Caribbean, the Philippines, the Soviet Union, and Indonesia. France had developed several space-heating projects at home and is conducting studies in her territories abroad. Other work is underway in several African nations. The present electrical output and near-future expansion plans for operational systems throughout the world are tabulated.

Barbier, E.; M. Fanelli. Non-Electrical Uses of Geothermal Energy. (National Research Council, Pisa, Italy). (1977).

The nonelectric applications of geothermal energy, with the exception of balneology, date back to the nineteenth century and have been given a new impetus by the recent oil crisis. In general, water or water-steam mixtures at temperatures between 20 and 180°C are used for these applications. The search for geothermal fluids draws on techniques from hydrogeology, geochemistry and geophysics, the same techniques as applied to the search for cold waters, together with some specific methods connected with the underground thermal conditions. Geothermal energy is used in agriculture, aquaculture, district heating and cooling, and various industrial

applications. The power associated with these used throughout the world at present can be estimated at 6200 MW and future prospects are by now promising and of definite economic interest. The environmental impact from geothermal energy is lower than that caused by conventional energy sources. Reinjection of used fluids back into the underground may, however, solve pollution problems.

Bloomster, C.H.; C.R. Schuller. Promise of Geothermal Energy Systems for Communities. 1978.

Geothermal energy has an excellent potential as a multipurpose renewable resource which may be developed over the next 25 to 50 years. Economics, the cost of production and distribution, and the organization of a market for end use are the main deterrents to its widespread use today. Worldwide, geothermal energy already is used for electricity generation, space heating, domestic hot water heating, industrial process heating, greenhouse heating, refrigeration, generating by-product chemicals, fish rearing, and therapeutic bathing. Over 1000 MWe of geothermal electricity are generated in the U.S., Italy, New Zealand, Mexico, Japan, Iceland, and U.S.S.R. New installations are planned in many of these and other countries. In Iceland, municipal district heating systems are geothermal energy to heat the homes of more than 100,000 people. Less-extensive geothermal district heating systems are located in France, Hungary, Japan, and the USSR. In the U.S., geothermal energy currently heats less than 1000 dwellings in Klamath Falls, Oregon, and Boise, Idaho. Many countries have geothermal process heat installations, but combined the total energy currently supplied is small.

Buch, A. Geothermal Heat and its Utilization. (Oct 1976). (In German).

A survey is presented of the possibilities to utilize geothermal power economically.

Capello, A. Method and Plant to Win Geothermal Energy. German (FRG) 17 Jul 1975. p. 17. (In German).

The following steps are proposed: feeding a heat exchanger fluid through at least one main feeding channel and into the soil down to a depth of some thousand metres; use of the potential energy released by the liquid as a result of its dropping-down for generating energy; feeding the liquid into the other soil after the predescribed use, ie. by additional supply pipes into a further depth of some thousand metres; vaporization of the fed-in liquid by the effect of the subsoil heat in the adjacent soil so as to form over heated vapour; leading the vapour to the surface; generating energy from the overheated vapour. A plant is described.

Denton, J.D.; R. Glanville, B.J. Gliddon, P.L. Harrison, R.C. Hotchkiss, E.M. Hughes, D.T. Swift-Hook, J.K. Wright. Potential of Natural Energy Sources. London; Central Electricity Generating Board (1976). p. 13.

Apart from fossil fuels and nuclear energy, five main alternative sources of power for electricity generation are: the sun, the wind, the waves, the tides, and the heat inside the earth. Each has been examined for its relevance to the energy situation in Britain and in particular to the DEGB's requirements as an electrical utility. None emerges from the analysis as directly competitive with nuclear power, provided that nuclear fulfills present expectations. As an insurance against unforeseen delays in the nuclear program, however, one or two of the options may well be worth closer consideration, particularly wave power, for which Britain is favorably placed. The best immediate prospect for using solar energy falls outside the province of the DEGB, in the area of domestic water heating. Wind power, despite the windiness of the British Isles, suffers in practice from a low load factor, which would greatly inflate the capital cost. Geothermal power in Britain, geologically one of the most stable parts of the world, appears to be available only at depths too great to be presently attractive for electricity generation. Finally, tidal power, although technically available in limited amounts, again suffers from high capital costs.

Haenel, R. Report on the Development of Geothermal Energy. (Niedersaechsisches Landesamt fuer Bodenforschung, Hannover (Germany, F.R.)). 28 Feb 1977. p. 5. (In German).

The total geothermal energy of the earth within 5 km depth is equivalent to 100 million terawatt/yrs. One percent of that amount would meet the world energy demand for 4000 years. In 1977, only naturally-occurring hot water and steam were being utilized for electricity generation. Natural warm water with temperatures of 50 to 150°C is used for domestic heating in the Federal Republic of Germany as well as other countries. In Hungary, thermal waters are used in greenhouses and agricultural soil to improve harvest yields. Approximately 7.5 GW of electricity were produced geothermally in 1975. Research is being carried out on improved methods of geophysical prospecting and on binary and ternary fluid systems. In the USA, hot dry rock systems are being researched at Los Alamos, New Mexico, particularly with respect to cost reduction in drilling and materials development. Other research is being conducted on increasing energy output through the addition of chemical reagents.

Hall, F.F. Solar, Geothermal, Hydrogen, and Hydraulic Power. (Stanford Linear Accel Cent, Stanford Univ, Calif). (Feb 1978).

Mankind faces a worldwide power dilemma. A comprehensive energy policy must be adopted here and abroad to solve this dilemma. Certain features of such a policy are considered including solar, geothermal, hydroelectric, and wind power plant applications. The possible use of weightless balloon collectors to reduce cost of solar-electric power plants is described. Present status of geothermal power plants is reviewed. The use of hydrogen as a fuel and for energy conversion, transmission, and storage is described. Possible uses of untapped or remote source of hydroelectric power are listed. The possible use of wind power is referred to.

Harris, F.A.; S.L. Phillips. International Geothermal Information Exchange. The GRID Program. (California Univ., Berkeley (USA). Lawrence Berkeley Lab.). Oct 1976. p. 21.

The need, potential, and current status of the GRID programs are presented in a general way. Some examples of data from GRID files are used as illustrations.

Jonsson, V.K. Geothermal Power Utilization, Present and Future. (Univ. of Iceland, Reykjavik), pp 279-324 of In Alternative energy sources. Hartnett, J.P. (ed). New York; Academic Press (1976).

The geology of Iceland and the chemistry of its thermal waters are described. Multipurpose uses of geothermal energy, current and prospective, are discussed. These are a diatomite plant, greenhouses, fish farming, seaweed drying, freeze drying, the Reykjanes salt plant, the magnesium project, heavy-water production, and recreational and health applications. Geothermal power generation is discussed under such headings as: power plants, material selection, power cycles, and operation of power plants. The district heating system in Iceland is discussed in the following areas: utilization of natural heat in Reykjavik, the district heating system equipment, operating conditions and costs, the proposed Nesjavellis project, and district heating in other parts of Iceland.

La Mori, P.N. Hydrothermal Geothermal Resources and Growth in Utilization. (Electric Power Research Inst., Palo Alto, CA pp 103-114 of In Energy technology III: commercialization. Bethesda, MD; Government Institutes, Inc. (1976).

An analytical relationship has been developed between the temperature and the number of hydrothermal systems. The information is sufficient to estimate various levels of potential development of the hydrothermal resources with temperatures high enough for electric power generation (T greater than 150°C) from a low of 100 up to a high of 450 for the eleven western states. Some impacts of the temperature distribution of this resource are examined. Previous estimates of the growth of geothermal electric power production are examined, and it is found that all but the most

conservative are too high for 1985. The present estimate for 1985 is less than 4000 MWe installed. The previous high estimates were all based on a significant increase in the growth rate of geothermal generation capability, usually occurring in the late '70s. The present information shows the past rate of installing generating capacity and its estimated growth to 1985 to be at the rate of 10x every 10 years. This is a large growth rate and should it continue to 1990, the installed MWe will be 10,000. The introduction and utilization of water-dominated systems in the early 1980s is necessary for this achievement. The introduction of power generation from geopressure and hot-dry rock resources is necessary for continued high growth beyond 1990.

La Mori, P.N. Growth in Utilization of Hydrothermal Geothermal Resources. (Electric Power Research Inst., Palo Alto, CA). pp 181-182 of In Geothermal: state of the art. Davis, CA; Geothermal Resources Council (1977).

Previous estimates of the growth of geothermal electric power production are examined and it is found that all but the most conservative are too high for 1985. The present estimate for 1985 is less than 4000 MWe installed. The previous high estimates were all based on a significant increase in the growth rate of geothermal generation capability, usually occurring in the late 1970s. The present information shows the past rate of installing generating capacity and its estimated growth to 1985 to be at the rate of 10x every 10 years. This is a large growth rate and should it continue to 1990, the installed MWe will be 10,000. The introduction in utilization of water-dominated systems in the early 1980s is necessary for this achievement. The introduction of power generation from geopressure and hot dry rock resources, or the discovery of significant new hydrothermal resources, is necessary for continued high growth beyond 1990.

Lenzer, R.C.; G.W. Crosby, C.W. Berge. Recent Developments at the Roosevelt Hot Springs KGRA. (Phillips Petroleum Co., Del Mar, CA). 1977.

The Roosevelt geothermal field, located in southwestern Utah, has been the focus of a high level of activity by both private industry and the academic community. Nine exploration wells have been drilled to depths ranging between 370 and 2300 meters into a late Tertiary granitic igneous complex. The reservoir is confined of fractures within the granitic and metamorphic rocks. The nature of the reservoir is such that all wells drilled are wildcats. The geothermal field lies along the west side of the central Mineral Range. Young rhyolite domes, with associated flows, pierce the late Tertiary granitic complex a few kilometers to the east and south of the producing wells. The heat at Roosevelt is probably supplied by the parent magma for the rhyolite domes. The resource is a water dominated geothermal system with a maximum temperature in excess of 265°C. The water is a sodium chloride water with

salinity less than 8000 mg/l. Recent activities include the formation of the Roosevelt Hot Springs Unit, applications to appropriate water from the state, the establishment of a groundwater monitoring system in the valley, and preparation for additional reservoir testing.

Milora, S.L.; J.W. Tester. Geothermal Energy as a Source of Electric Power. Thermodynamic and Economic Design Criteria. Cambridge, MA; Massachusetts Institute of Technology (1976). p. 194.

The resource base and its potential environmental impact are assessed. Power cycle and resource utilization efficiencies are described with empirical equations and correlations. Detailed cycle calculations performed with seven representative working fluids that were selected to illustrate a range of molecular properties are presented. Turbine and pump design criteria are discussed. An economic model is developed based on separate cost equations or correlations for the major power plant components and geothermal wells. It is concluded that geothermal power generating costs can compete with the present escalated fossil-fuel and nuclear generating costs, and that geothermal resources are large enough to have an impact on our energy economy.

Paris, L. Prospects for Geothermal Energy. (Corporate Unverified). 1977. p. 17.

Precise evaluation of geothermal resources is difficult, and can be done only on a short-term basis. At present, only high temperature geothermal fields are being exploited for electricity production. Those fields now having operational power plants are of the vapor-dominated or water-dominated type. Low-temperature fields are being used to some extent for industrial process heat, space heating, and agriculture, usually in areas immediately adjacent to the heat source. The geothermal fields of Italy and the United States are described and evaluated. Geothermal energy should not be viewed as an alternative energy source, but rather as an integral part of the energy resource system. Several more years of study will be required for determination of the feasibility of hot-dry-rock systems. Five references are provided.

Ruiter, J.P. Alternative Energy Sources. (Mar 1975). (In Dutch).

The possibilities of some nonconventional energy sources such as solar radiation, tidal energy and geothermal energy are described. Also the sources derived from the solar radiation such as wind, temperature differences in the oceans and organic wastes are included in this survey.

Sekioka, M. Application of Geothermal Energy in Addition to Power Generation. (Defense Academy, Dept. of Geometry, Japan). (1975). (In Japanese).

Although the primary thrust of geothermal research is towards electrical power generation, the hot water generated as a by-product can be used in many diverse applications. Most common among these are the heating and cooling of domestic swellings, agricultural areas, fish ponds, therapeutic baths and roadways. Steam can be used to generate electricity by direct application in turbines, or, at lower temperatures, by vaporizing a secondary fluid such as freon or isobutane. After use in power generation equipment the remaining thermal energy can be extracted and used for domestic water heating. It is advisable to utilize the greatest possible amount of heat energy prior to discharge of the fluid into the environment. Secondary heat extraction of this type is performed at the Hatchobara and Otake geothermal fields as well as at Matsukawa. At the Onuma geothermal field 260 t/h of weakly alkaline hot water is used for therapeutic bathing purposes. Tables giving the power output in kW of geothermal fields in the US, Japan, Italy, New Zealand, Mexico, El Salvador, the Philippines, Iceland and the USSR are provided.

Smith, C.; P. Morgan, G. Jiracek, C.A. Swanberg. NMSU Annual Energy Conference: Geothermal Energy. (Jul 1976).

Papers were presented on a wide range of geothermal related subjects, including geothermal processes, the search for and evaluation of geothermal resources, and the economic, political, legal, environmental, and institutional problems associated with geothermal development. Progress reports were given on essentially all geothermal programs in New Mexico. A synopsis of the conference papers is given. Selected geothermal references for New Mexico are also given.

Smith, M.F. Geothermal Energy. Volume I. 1964--April 1975 (citations from the NTIS data base). Report for 1964--Apr 1975. (National Technical Information Service, Springfield, Va. (USA)). Jun 1976. p. 153.

All aspects of geothermal energy are covered including development, prospecting, technology, and corrosion problems. This updated bibliography contains 148 abstracts.

Stone, C.D. Proceedings of Conference on Geothermal Energy and the Law. (University of Southern California, Los Angeles (USA). Law Center). 1975. p. 77.

Work group reports are presented for the following problem areas: legal and other institutional barriers complicating efforts at the earliest stages of geothermal development; the perspective of potential investors and the connection with specific uncertainties in the legal environment; preserving the interests of the government, the public generally, and the private geothermal lessors;

the various water law conflicts, including potential conflicts between users of water in geothermal production and users of water for other purposes; jurisdictional conflict and overlapping administration; and problems of utilities and dependent users.

Tucker, F.L.; M.D. Anderson. Geothermal Environmental Seminar, '76.
(eds). (Geothermal Seminar, Lakeport, Calif.(USA)). 1976. p.
295.

Thirty-three papers were abstracted and indexed individually for ERA/EDB.

APPENDIX F
COAL AND COAL GASIFICATION BIBLIOGRAPHY

ECONOMICS
ENVIRONMENTAL IMPACTS
GENERAL INFORMATION

COAL-ECONOMICS

California Energy: the Economic Factors. San Francisco; Federal Reserve Bank of San Francisco (1976). p. 210.

A separate abstract was prepared for each of the eight invited papers on California's future energy sources. The objective was to provide more information on the economic aspects of energy use and energy technology, with emphasis on nuclear power. It is pointed out that the Federal Reserve Bank takes no position on the question of an appropriate energy policy, and that this publication arrives at no single conclusion on the merits of the nuclear initiative or nuclear power generally. (LMT)

Mining and Minerals Policy: 1976 Bicentennial Edition. (Department of the Interior, Washington, D.C. (USA)). Jul 1976. p. 135. GPO.

The report is organized into three basic parts. The first part, the Executive Summary, provides a brief description of the major topics and lists the issues and recommendations. The report then is divided into two sections. Section I, Summary, is comprised of three chapters: Increased Energy Security; Metals and Nonmetallic Minerals; and Trends and Events. Section II, Issues in Energy and Minerals Policy, is comprised of seven chapters: Federal Leasing; The Federal Role in Reducing the Fiscal Impacts of Energy Development; Availability of Federal Lands for Mineral Exploration and Development; Environmental Issues and the Mineral Industry; Developments in International Minerals Trade and Investment; Ocean Mining; and The Development of New Tools for Energy and Minerals Policy Analysis. (MCW)

Auer, P.L., A.S. Manne, O.S. Yu. Nuclear Power, Coal, and Energy Conservation. Special Report. (Electric Power Research Inst., Palo Alto, Calif. (USA)). Mar 1976. p. 35.

A programming model is used to explore options by which the U.S. may realistically move from its dependence on oil and gas to a more diversified energy economy based on nuclear power and/or coal. Supply options considered are: direct combustion of coal; conversion of coal to synthetic fuels; petroleum, natural gas, and oil shale resources; nuclear energy from light water and fast breeder reactors; hydrogen via electrolysis; solar power; and fusion. (GRA)

Bennenewitz, G.A. Jr. Markets and Costs for Western Steam Coal. (Denver and Rio Grande Western Railroad Co.). pp 8p, Set No. 7, Paper 2 of 1977 mining convention of the American Mining Congress. Session papers. Washington, DC; American Mining Congress (1977). From Mining convention; San Francisco, CA, USA (11 Sep 1977).

Western coal can find a place in the market throughout the country, provided its use is not restricted through a mandate for scrubbers, or use of local coal. Western coal is not homogeneous, that is to say all thick-seam, low-Btu, but substantial reserves of high-Btu coal exist that are compatible with some existing sources in the East, as far as load-carrying capability. As other fuels become more scarce and higher-priced, coal will be able to find a place as the fuel in cement plants, pulp and paper plants, and canneries; but the West will still be a net exporter of coal, as its coal reserves far exceed the available market in the West.

Berkovitch, I. London; George Allen and Unwin Ltd. Coal on the Switch-back: the Coal Industry Since Nationalization. (1977). p. 237.

In recent decades world energy consumption has increased at a compound rate of about 5 1/2 percent per annum. In meeting this demand, coal has lost ground to oil and natural gas. A major consequence has been growing dependence on imported fuels--particularly oil from Arab countries--by all the industrialized countries, including the USA, until recently a fuel exporter. Yet coal has by far the greater reserves. Britain broadly followed world trends in the period after the Second World War, at first seeking to build up its coal industry, then systematically closing it down in pursuit of a cheap fuel policy, interfering little with the switch to cheaper oil. What was the background to this policy? How do the chief actors now justify their parts in that drama that led the country close to the risk of economic strangulation? Both official and unofficial explanations of these central issues of policy are treated and analyzed in some detail in the later chapters of this book. By 1974, the newly arrived Labour government, after the reappraisals following the rapid five-fold increase in oil prices, expressed a commitment to building the coal industry. It also took major decisions on nuclear policy which, despite massive investments, was contributing only some 3 percent to the primary energy input. And, of course, oil from the North Sea was expected to make Britain a net exporter of oil from about 1980, while further discoveries of gas promised a greater contribution of this fuel to future energy supplies. Repercussions of these new features form the theme of the concluding chapters.

Berndt, E.R.; M.A. Fuss, L. Waverman. Dynamic Models of the Industrial Demand for Energy. (Economics Research Group Ltd., Toronto, Ontario (Canada)). Nov 1977. p. 147.

Econometric approaches to modeling the demand for electricity, petroleum, coal, and natural gas by the manufacturing sector of the U.S. economy are investigated. Important aspects of the research are incorporation of dynamic effects, as well as an introduction of the impact of technological change on energy usage. The first model analyzed is the ad hoc partial adjustment model applied to a system of equations. Extending the work of Rosen and Nadiri (A.E.R. 1969) and Berndt and Savin (Econometrica, Sept./Nov. 1975), the authors show that ad hoc models applied to flexible functional forms such as the translog or generalized Leontief have a number of undesirable features: (1) short-run own-price elasticities may exceed long-run elasticities, thus violating the Le Chatelier principle; and (2) for the translog, if the adjustment matrix is diagonal, all rates of adjustment must be equal; specification of a general adjustment matrix leads to underidentification of the adjustment parameters. The above two problems and others are illustrated using data drawn from U.S. aggregate manufacturing 1948 to 1971. A second model is developed from the cost-of-adjustment literature associated with R. Lucas and A. Treadway. It is shown that the Lucas and Treadway models can be implemented empirically to overcome the theoretical objections to the ad hoc partial adjustment models. In particular, the econometric model cannot violate the Le Chatelier principle and contains a generalized endogenous (non ad hoc) partial adjustment mechanism. An analysis of the effects of an investment tax credit on both the long-run demand for energy and the adjustment path to the new long-run equilibrium demand is made. Several models are considered that can be utilized in an analysis of endogenous technical change. The most promising model for future research is one which incorporates knowledge as a quasifixed factor within the cost of adjustment framework.

Buck, L.E. Coal Utilization. (Patton, Boggs and Blow, Washington, DC). pp 74-89 of In Energy users law 1977. (ed.) Washington, DC; Government Institutes, Inc. (1977). From Energy users law seminar; Washington, DC, USA (27 Jan 1977).

The Energy Supply and Environmental Coordination Act of 1974 (ESECA) was designed to authorize coal conversion for existing plants and coal utilization for new plants. The law's intent, provisions, and implementation procedures are summarized. Pertinent definitions are given for clarification. The sequence of prohibition, construction, and supply orders is listed and defined. A summary is given of the law's requirements for findings, coal allocations, data compilation, and reporting intervals. (DCK)

Bund, K. Coal Price Formation: Principles and Practice. Glueckauf; 112: No. 24, 1284-1391 (16 Dec 1976). (In German).

Cost of energy as function of economic and policy factors is discussed. Consumers' demand by industry and utilities is analyzed. Flexibility model of demand and supply is presented.

Christiansen, B. Western Perspective on Energy: A Plea for Rational Energy Planning. (Lieutenant Governor of the State of Montana); Clack, T.H. Jr. Science; 194: No. 4265, 578-584 (5 Nov 1976).

The immense reserves of the Rocky Mountain region are perceived to be the short- and mid-term answer to the energy crisis. The Federal government and the energy industry have prepared plans to develop western energy resources; these reserves would be of far greater value as future sources of hydrocarbons than as simple fuels for the present. Two major Federal plans show that the public is not aware, nor has it been informed, that severe energy, food, and materials shortages are imminent. The first proposal outlines the administration's plan to achieve the objectives of Project Independence. The second document, issued by the Department of the Interior in 1974, outlines the Federal government's plans to expand leasing of Federal coal lands and the reasons for doing so. The impacts not cited or considered in the documents are then reviewed. While admitting it is easier to criticize than to find solutions, the authors discuss five suggestions: the problem should be rationally and comprehensively assessed; specific plans must be developed; alternative energy futures should be considered; a commitment to preserve natural and social values is necessary; and commitment to public access and information is essential. The public and their elected representatives must define the optimum use of the nation's remaining energy reserves before an irrevocable decision is made concerning their fate. (MCW)

Davies, D. Place of Coal in the Energy Market. (Nat'l Coal Board). Min. Eng. (London); 136: No. 194, 615-618 (Jul 1977).

The author argues that through its Plan for Coal the British coal industry is settling itself in good shape to meet the fuel needs in the latter years of this and into the next century when reserves of other fossil fuels will be greatly depleted. There are, however, short-term problems in the market which must not be allowed to divert the industry from its longer-term objective, and the author discussed market by market the problems and short- and longer-term action required to be taken.

Falkie, T.V. Economics of Coal Supply. pp 3-28 of In Proceedings of a symposium on coal dilemma: how and where to use it. Denver; Cameron Engineers, Inc. (1976).

An overview of U.S. energy problems and policies is presented. As of October 1976, delivered prices per million Btu of fossil fuels at steam electric plants average \$0.87 for coal, \$1.10 for natural gas and \$1.94 for oil. The price of oil is more than 4 times that of 1973 and the price of other alternative fuels has more than doubled. Electric power from nuclear power plants is estimated to be modestly lower in cost than that from coal-fired plants (with some reservations about the level of capacity utilization). Certain problems in using coal are discussed. Sulfur content of Eastern coal, transportation cost of Western coal, scrubbers, environmental effects (Clean Air Act), uncertainties in government policies, leasing and mining regulations, productivity of labor, health and safety, etc. The U.S. Bureau of Mines coal research programs are discussed briefly. Coal is regarded as the only real energy possibility and the ability of the country to reach a consensus on energy policy is unnecessarily delaying the construction of badly needed energy facilities. (LTN)

Gaertner, E. Coal - Present and Future Uses as an Energy Source and as Raw Material. Glueckauf; 113: No. 1, 34-38 (Jan 1977). (In German).

Coal, representing the largest and most important reservoir of energy and raw material in the world, will regain its former importance in the near future. This is not only due to the fact that the profitability of energy and raw materials exploitation of other resources is increasing because of the increase in prices of today's important energy source (petroleum and natural gas). The demand for coal, particularly for its refined product, coke, will be so high that a bottleneck for coke amounting to about 100 million tons is expected for 1985. Later research results on the better use of coal are concentrated on the continuous production of formed coke, on higher efficiency concerning electricity generation of coal gas and coal oil. In the near future, brown coal will be important than pit coal, because it can be exploited cheaper, mainly in subsurface open-pit mining. According to latest research, brown coal will be used to an increasing extent for generating synthesis gas due to conditions which are favorable for the gasification of coal (mainly due to the use of heat generated by high-temperature nuclear reactors) and for the production of synthetic (natural) gas.

Gambs, G.C. New York; Ford, Bacon and Davis, Inc. Coal Option: Constraints to Growth. Issues, Impacts, Solutions. (1977). p. 41.

The author states emphatically that the U.S. is in danger of being destroyed due to its lack of action to develop our domestic supplies of oil, gas, and coal. The inaction could result in the collapse of the U.S. as an industrial nation. Seven actions that must be taken now to prevent catastrophic effects are suggested, namely: (1) decontrol prices for new natural gas; (2) decontrol prices for all crude oil; (3) amend the Clean Air Act to allow burning of high-sulfur coal through use of intermittent control systems; (4) remove obstacles to mining of coal through amendments to the Federal Mine Safety Act and Federal Coal Leasing Act; (5) remove obstacles to the construction of nuclear power plants; (6) pass legislation to provide for the incentive for energy conservation such as 100% depreciation on the first year for installation of coal-fired boilers and energy-conservation equipment by industry and similar tax incentives to home owners for installing insulation, etc.; and (7) pass legislation to provide for \$1.00 per gallon tax on gasoline to encourage conservation of petroleum and tax revenue to be used for mass transportation and synthetic-fuel projects. (MCW)

Garcia, A. Assessment of Potential for Colloidal Fuels. Technical Report. (Midland Coal Co., Trivoli, Ill. (USA)). Jun 1975.

Colloidal fuels, consisting of a combination of residual fuel oils as the basic carrier with coal added in particulate form have been evaluated throughout the 20th century. They received considerable attention during World War I and II as potential fuel substitutes in the event petroleum sources were interrupted. The investigation of the potential of colloidal fuels reported herein was stimulated by the issue of a report by Battelle Columbus Laboratories (BCL) on the potential application of colloidal fuels by the DOD. The BCL report indicated that a complete conversion to colloidal fuels could provide DOD fuel savings of 200 to 400 million dollars per year. The primary conclusion of this reassessment is that the net savings potential of colloidal fuel appears too small and far too limited a market to indicate any significant economic advantage for either DOD or the nation. However, this conclusion should not preclude pursuing further research of colloidal fuel. Colloidal fuel would be a means of using vast U.S. coal resources to extend limited petroleum energy resources. Colloidal fuels could at least provide an alternate energy source for reducing residual fuel requirements should another fuel crisis occur. The technological base for colloidal fuels should be expanded so that the lag time required to develop the colloidal fuels will not interfere with the eventual or emergency implementation of these alternate fuels. Colloidal fuels should be researched and continually reconsidered for production as the economic environment changes in the future. (GRA)

Gordon, R.L., M.A. Lexington, D.C. Heath and Company. Coal in the U.S. Energy Market: History and Prospects. (1978). p. 236.

A survey of the history and prospects of the USA coal industry recognizes two basic problems--the enormous uncertainties that exist about world energy resource endowments and prospective technological progress and the pervasive role of public policy in influencing coal production and use. Chapter 1 deals with public policy and other problems. The following 5 chapters are: The History of U.S. Coal Consumption Patterns; Forecasting Coal Consumption; The Economics of Coal Production and Distribution; The Economics of Coal Utilization; and Scenarios of Electric Utility Fuel Use. (MCW)

Greeley, R.S. Coal Markets and Transportation Problems. (Mitre Corp., McLean, VA). 1977.

The near-term future for coal transportation is unfortunately uncertain. Clearly additional equipment and facilities will be needed, along with upgraded system control. However, the number of additional coal cars, locomotives, barges and trucks that will be needed are not known to a significant degree. The need to increase the capacity of certain transportation links is very sure. However, the required capacity increase is still quite uncertain. In the long term there could be a requirement for a vastly increased coal-transportation network together with significant increases in electrical transmission lines, oil pipelines and gas pipelines. Again, unfortunately, specific locations, capacities and number of miles are at this point completely uncertain. There will need to be great flexibility in planning for the expanding of the U.S. transportation system to meet the future successfully.

Guerns S.A. Achieving Energy Self-sufficiency With Coal. (Delaware Univ., Newark (USA)). Arch. Energiewirtsck; No. 11,920-933 (Nov 1977). (In German).

The report deals with an alternative to the ERAD plans for the utilization and conversion of coal. Combinations of solid, liquid, and gaseous fuels are investigated which pursue the target of the ERDA, while meeting the US demand with minimum energy and expenditure, and gaseous fuels are investigated which pursue the target of the ERDA, while meeting the US demand with minimum energy and expenditure for the production and consumption of these fuels. The following issues are dealt with: a) effects of the changing over of electricity production from oil and natural gas to coal on the one hand, and from coal cokes with simultaneous yielding of coal gas and synthetic crude oil as side-product on the other hand, and b) effects of coal giving for electricity production with separate conversion of coal to synthetic natural gas and synthetic crude oil. A total comparison is made of the alternative methods investigated. The report concludes with recommendations on the coal policy and that of oil shale.

Hill, G.R. Critical Paths to Coal Utilization. (Electric Power Research Inst., Palo Alto, CA). Int. J. Energy Res.; 1: No. 4, 341,349 (1977).

The present dilemma of energy producers, converters, and policy decision makers is presented. The consequences of environmental control regulations, coupled with the need for conservation and energy, and of energy resources on the increased utilization of coal, are discussed. Several recent technical accomplishments that make possible increased utilization of coal for power generation are described. Groundwork is laid for discussion of the technical development that must occur if the United States is to retain its energy viability.

Holmes, C.D. Coal: Energy for the Future. (National Coal Association, Washington, DC). pp 51-73 of In Energy users law 1977. Buck, L.E. (ed). Washington, DC; Government Institutes, Inc. (1977).

The lack of a coal policy has meant that, while coal is to be our major source of energy, legislation that is passed will either impede or make it easier to mine, move, and burn coal. The logic of emphasizing coal is apparent in view of the size of U.S. coal reserves relative to oil and gas. The coal industry is confident that it can meet the challenge of increasing production if managerial and legislative obstacles are dealt with. Managerial problems include the recruiting and training of miners for efficient production while keeping health and safety as a top priority. The industry can initiate people-oriented programs that will accomplish this and increase productivity at the same time. These programs should include better relations between labor and management and between regulators and the regulated, new mining and transportation equipment, and a better climate for capital formation. Legislative constraints in the area of strip mining have been shifting from Federal to state and industry control in recent years. Federal environmental and leasing laws at this stage could serve to impede productivity. Legislation requiring oil companies to divest their coal holdings and industrial plants to meet the Clean Air Act standards are viewed as counterproductive. (DCK)

Huegel, L.J. Marketing and Transporting Coal. (Consolidation Coal Co., Pittsburgh). pp 21-27 of In First symposium on coal management techniques. Volume II. Washington, DC; National Coal Association (1975).

Mr. Huegel points out that while the various markets for coal--electric power, metallurgical uses, industrial uses, and conversion--should grow (in varying degrees), there are some imponderables under the general heading of "constraints" that the coal industry must overcome to satisfy these markets. Among these constraints are labor instability, Federal legislation, declining productivity, investment capital, and transport; all of these are elaborated to

some extent. In addressing the problems of transport, Mr. Huegel doubts that slurry pipelines will be a factor during the next ten years. He sees expansion capital and greatly improved transportation as the two paramount needs. (LMT)

Ippolito, M. Use of Coal in Power Plants. (Charbonnages de Fr). Rev. Energ.; 28 No. 291, 102-110 (Feb 1977). (In French).

After pointing out that coal still supplies half the world's power plants, the question is asked whether this present situation guarantees the future. Taking account of electricity consumption and nuclear energy production scenarios, the position that fossil fuels could hold in the supply model from now until the end of the century, both throughout the world and at the level of large complexes, is analyzed. It is shown that the recourse to solid fuels appears indispensable to stabilize the system and enable safe development of nuclear programs.

Krohm, G.C.; J.C. VanKuiken. National Coal Utilization Assessment: Effects on Regional Coal Markets of the "Best Available Control Technology" Policy for Sulfur Emission. (Argonne National Lab., Ill. (USA)). Dec 1977.

This report analyzes the effects on regional coal markets of a policy requiring the "Best Available Control Technology" (BACT) for sulfur emissions. Four likely BACT implementation strategies are defined and tested in a detailed model of U.S. coal markets. The study estimates the effects of BACT on regional coal production, interregional shipments, and coal utilization costs. Initially, any BACT policy will have small effects on coal markets but will substantially alter market patterns between 1985 and 1990. With or without BACT, production levels in the Northern Great Plains will remain at boom levels through about 1985. Differences in regional production shares among alternative BACT scenarios are minor in 1990 and almost negligible in 1985. Alternative BACT policies do not significantly change the cost of burning high sulfur coal. Once the use of scrubbers is required, variations in the sulfur removal efficiency between 75% and 90% have minimal effects on the total cost of using coal. This helps to explain why the differences in market impacts among the four scenarios are generally insignificant. BACT policies will have two effects on coal combustion costs. In those areas where Western low sulfur coal is now used to meet NSPS, the costs of coal utilization (fuel plus control costs) will increase by 20 to 25%. In those areas where Eastern high sulfur coal is being used to meet NSPS, costs will increase by only 8 to 10%. In both cases, the increased costs will make coal-generated electrical power more expensive relative to nuclear power. This should widen the apparent cost advantage of nuclear plants in many areas. For those utility applications where coal is still a competitive fuel, the costs of power will increase by at least 2 mills/kWh.

Lee, L.C. Status and Future of Federal Coal Leasing. (Bureau of Land Management, Washington, DC). pp 122-128 of In Mining yearbook, 1976. Denver; Colorado Mining Association (1976).

A new coal land leasing policy was announced by the U.S. Department of Interior January 26, 1976. The reevaluation which led to the new policy is discussed; certain details of the policy and the plans and goals that the policy is expected to achieve are given. Briefly, the aim is to make available energy supplies which can be obtained with the least effect on the environment and in accordance with alternative land uses. Compliance checks and operations reports of the leases, particularly with respect to land reclamation, are discussed briefly. (LTN)

Levine, R. Fuel Adjustment Clause. Part I. Coal and the Coal Market: a Primer. (Georgia Office of the Consumers' Utility Counsel, Atlanta (USA)). Mar 1978. p. 108.

The structure and substance of the relationships that constitute the market for steam coal are outlined.

Lewis, L.R. Potential Demand for Western Coal in the Northeastern United States and its Relationship to Waterway Transportation Facilities. (Argonne National Lab., (USA)). 17 Jan 1978. p. 5.

Preliminary studies indicate that a potential exists for a movement of large amounts of Western coal through the Port Buffalo. In response to increasing interest in Western coal utilization along the southern Great Lakes and in New England, and consideration for the possible beneficial effects such utilization must have in relieving chronic unemployment problems in the western New York area, the New York area, the New York State of Development Authority and the Niagara Frontier Transportation Authority have proposed and begun planning for a coal and by-commodity transshipment terminal to be located at Buffalo. The facility will have the capability of handling 12 million tons per year of Western coal, and will be designed to accommodate unloading and storage for taconite ore, iron ore pellets, and ferro-chromium ores. When completed, Conrail connections will transport coal by inland and lakeside users, with a potential for rail shipment of utilities in Massachusetts and Maine. In terms of potential volumes of coal moving through the system, present information indicates that as much as ten million tons per year may be anticipated by 1985. Cite studies indicate that potential savings of up to \$4.00 per ton may be realized by New England utilities through the use of Western coal as opposed to Appalachian coals shipped up the East Coast. The reason lies in lower f.o.b. mine costs for the coal, and higher railroad rates from Appalachian coal fields to East Coast port facilities.

Morse, J.G.; D.H. Hebb. Colorado Energy Resources Handbook. Volume I. Coal. Golden, CO; Colorado Energy Research Institute (1976). p. 60.

The handbook provides policymakers in Colorado with current and primarily factual data on the resources of the state and impact of technology associated with their development as a basis for sound decision making. The nature of the coal resource is examined in the first chapter followed by chapters on exploration, recovery methods, capital investment estimates, coal use in Colorado, technology developments affecting coal use, environmental impact, mining safety, manpower requirements, community impacts, and future observations and concerns. Future volumes in this series will cover oil shale, uranium natural gas, petroleum, geothermal sources, solar energy, wind, and water availability for future energy-resource development in the state. (MCW)

Wilson, W.W. Markets for Utah Coal. (Continental Illinois National Bank and Trust Co., Chicago (USA)). 1976. p. 9.

Utah coal is not now competitive with subbituminous steam coal produced in Montana and Wyoming, for markets generally east of Utah. The economic advantage of Utah coal's higher heat content is more than offset by higher production costs and low-volume freight rates. Most of the best future markets for Utah coal will be in the western and southwestern states, and for eventual gasification within Utah. Utah coal producers will be competing at a substantial economic disadvantage with producers in Wyoming and Montana, at least until new large-volume markets develop and total coal output is sufficient to warrant unit-train transportation. New taxes or other economic disincentives to the marketing of Utah coal will be largely counterproductive, by still further increasing its cost in available markets.

Zahradnik, R.L. Overview of the Government's Programs in Coal Conversion, Research and Development. (Energy Research and Development Administration, Washington, DC). (19 Sep 1976).

The Federal Government is currently sponsoring a large effort of research and development in coal conversion and utilization. This effort is cost-shared with private industry to a significant extent and is directed toward the establishment of a viable coal conversion industry in the United States by the mid 1980's. The program plans, current activities and achievements, future directions, and funding levels are discussed.

COAL-ENVIRONMENTAL IMPACTS

Biological Services Program, Fiscal Year 1975.
Annual Report No. 1. (Fish and Wildlife Service, Washington, D.C.
(USA). Office of Biological Services). Apr 1976. p. 52.

The Biological Services Program was initiated in 1974 as an information bridge between research and field operations within the U.S. Fish and Wildlife Service. Information provided to decision makers aids in accommodating fish and wildlife values in programs associated with energy research and development and land and water development. Project areas include terrestrial habitats and fauna disturbed by oil shale, coal, or geothermal development; freshwater impingements associated with water allocation and stream channelization; and coastal and offshore management. The FY budget for the base program was \$4,412,000 plus \$3,510,000 in funds transferred from other agencies. A directory for 107 staff members is attached. (GRA)

Ayres, R.E. Environmental Overview. (Natural Resources Defense Council,
Washington, DC). Nov 1977.

The environmental effects of coal use in industrial boilers are discussed. Sulfur oxides emissions are examined along with concerns of increased acidity in rainfall and increased nitrogen oxides emissions. The technology of flue gas cleanup is briefly discussed. (JRD)

Barnes, H.M.; J.B. Homolya. Data Requirements for NO/sub x/ Emission
Monitoring From Fossil-fuel Fired Steam Generators. (EPA, Research
Triangle Park, NC). (1976).

The SPNSS promulgated by EPA requires installation of continuous monitors on selected sources for SO₂ and NO/sub x/ measurements. This paper supplies data on [NO/sub x/] variability as a function of time from a coal-fired power plant. The data supports the conclusion that NO/sub x/ concentration measurements can be made each 15-30 minute period to represent adequately the source emissions.

Bencko, V.; K. Symon, V. Chladek, J. Pihrt. Health Aspects of Burning Coal With High Arsenic Content. II. Hearing Changes in Exposed Children. (Charles Univ., Prague). Environ, Res.; 13: No. 3,386-395 (Jun 1977).

Hearing changes were analyzed after audiometric and clinical otorhinolaryngological examination of a group of 56 10-year-old children residing near a power plant burning local coal of high arsenic content. The results of both audiometric and clinical examinations were compared with those of a control group numbering 51 children of the same age living outside the polluted area. The highly standardized audiometric and clinical examinations were completed with a questionnaire analysis concerning the personal medical histories of the children. The data obtained were elaborated statistically by means of the chi test. It was found that in the case of air conduction, important hearing losses were found at frequencies of 125,250, and 8000 Hz, especially at the lowest frequency range. Significant degrees of hearing loss were found in bone conduction as well as in the corresponding ranges of frequencies. The results of clinical examination including the vestibular one are discussed in detail. While an assumed influence of the anamnestic presence of middle ear inflammation is fully documented in the control group, such does not appear in the exposed group. The high statistical significance of the hearing impairments found points to a very low probability of there being only an "accidental" finding. The possibility of central damage to the ear cannot yet be excluded.

Brocksen, R.W. Ecological Analyses and Applications. Nov 1977.

Progress is reported on the following: analysis of ecological impacts of construction and operation of nuclear power plants; fossil energy environmental project; ecological analysis of geothermal energy development; HUD modular integrated utility systems; expansion of uranium enrichment facilities at Portsmouth; environmental standard review plans; environmental assessment of cooling reservoirs; and analysis of fish impingement at power plants in the southeastern United States. (HLW)

Horton, J.H. Effect of Stack Releases From a Coal-fired Powerhouse on Trace Element Contents of Neighboring Soil and Vegetation. (Savannah River Lab., Aiken, SC). May 1977.

The Savannah River Plant 400-D Area powerhouse has operated since 1952 and consumes about 360,000 kg of coal per year. From startup until late 1975, this powerhouse operated without electrostatic precipitators. The objective of this study is to estimate the quantities of trace elements released before electrostatic precipitators were installed and to determine the influence of these releases upon the trace element content of surrounding soils and vegetation which are typical for much of the Coastal Plains of the Southeastern United States. Results to date indicate that none of

twenty-six trace elements which have been measured in fly ash have produced measurable effects on the concentrations in soil or vegetation; however, mercury (not normally associated with fly ash because of its volatility) concentration in surface soil does appear to be influenced by stack releases.

Marland, G.; R.M. Rotty. Question Mark Over Coal, Pollution, Politics, and CO. (Oak Ridge Assoc Univ, Inst for Energy Anal, Tenn). (Feb 1978).

The increasing concentration of carbon dioxide (CO₂) in the atmosphere is now well-documented, and although the evidence of actual or potential climate changes is not conclusive, the growth in energy consumption magnifies the importance of the possible dangers. The CO₂ increase will be mainly produced by coal, and the indications are that many countries will be contributing to the increase in atmospheric CO₂ early in the next century. Using world energy resource estimates and projections of the global production of CO₂ from fossil-fuel burning in the year 2025, the paper argues that it will be difficult to achieve an international consensus and commitment to deal with the issue. This is because of the relationship between economic growth, industrialization, and the production of CO₂, and because of the distribution of the beneficial and harmful effects of any climatic change. 28 refs.

McGuire, H.E. Jr. Effect of Liquid Waste Discharges From Steam Generating Facilities. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Sep 1977.

This report contains a summary of the effects of liquid waste discharges from steam electric generating facilities on the environment. Also included is a simplified model for use in approximately determining the effects of these discharges. Four basic fuels are used in steam electric power plants: three fossil fuels--coal, natural gas, and oil--and uranium, presently the basic fuel of nuclear power. Coal and uranium are expected to be the major fuels in future years. The following power plant effluents are considered: heat, chlorine, copper, total dissolved solids, suspended solids, pH, oil and grease, iron, zinc, chrome, phosphorus, and trace radionuclides.

Moscatti, A.F. Jr. Environmental Issues in the Siting, Construction, and Operation of New Coal-fired and Nuclear Power Plants. Los Angeles; Univ. of California (1975). p. 197.

A discussion is presented of some of the major interfaces between efforts toward environmental preservation and the expansion of the nation's power supply. Ways in which environmental goals may be attained within the framework of the comprehensive energy policy are also discussed. The study is limited to an examination of

the environmental issues encountered in the siting, construction and operation of new coal-fired and nuclear power stations; no attempt is made to evaluate environmental aspects of such related activities as fuel mining, processing and recycling. Recommendations made concerning the integration of environmental concerns into the regulatory framework include suggestions for streamlining the environmental review process. The report includes a summary of the internship served with Bechtel Power Corporation under the auspices of the Environmental Science and Engineering Program of UCLA.

Murr, L.E.; K.R. Brower, K. Wongwiwat. Structural, Mechanical, and Chemical Factors Affecting Coal Liquefaction and their Relationship to In Situ Liquefaction of Coal. (New Mexico Inst. of Mining and Technology, Socorro). 1977.

Laboratory studies of a total of 17 coals (primarily subbituminous) and ranging in occurrence from surface coals to 2500 ft deep seams have indicated that the physical structure of coal, while it varies somewhat with depth, does not have a measurable influence on the ability of the coal to be liquefied by solvent extraction methods. High sulfur content is demonstrated by observations in the scanning electron microscope to be characterized primarily by pyritic inclusions, but there was no correlation of sulfur content with depth of occurrence. A correlation was observed between coal surface hardness and depth, with hardness generally increasing with increasing depth. Similarly, liquefaction yield by solvent extraction (primarily with tetralin) was shown to increase with an increase in carbon content (in the range 43-83 percent C), while the hardness was shown to increase correspondingly with an increase in carbon content. Liquefaction yield by solvent extraction was also shown to be significantly influenced by oxygen content, increasing with a decrease in oxygen content. The oxygen content was also observed to decrease with increasing depth of occurrence. By comparison, liquefaction yield by hydrogenation was observed to be essentially constant and independent of either carbon or oxygen content in the range of samples investigated. These results seem to indicate, perhaps somewhat fortunately, that the deeper coal seams would tend to be more readily liquefied by solvent extraction methods. The requisite conditions for fluid retention and pressure sealing are discussed in the context of in situ liquefaction of deep coal seams by solvent extraction methods, and the ability to form and propagate cracks in a deep-seam coal structure as it may be influenced by the physical and mechanical properties of the coal is discussed in relation to the direct observations of coal structure made in this investigation by scanning electron microscopy.

Richmond, C.R. Energy, Environment, and Health: What Can We Learn From the Nuclear Experience. (Oak Ridge National Lab., Tenn. (USA)). 1976.

The author discusses the fallacy of ever thinking cost-benefit analysis of health and environmental effects can fully be quantified and cautions about premature solutions to the environmental problems of energy supplies. Comparison between nuclear energy and coal relative to environmental assessments is given in hopes that decision-makers may avoid the pitfalls of the past. (PCS)

Roxin, C.L.; M. Tinkleman. Potential for Conversion to Coal as a Fuel by Major Fuel Users in the Pennsylvania Counties of Bucks, Chester, Delaware, Montgomery, and Philadelphia. Final Report. (Delaware Valley Regional Planning Commission, Philadelphia, Pa. (USA)). Dec 1974. p. 71.

Sharkey, A.G. Jr. Mass Spectrometric Analysis of Process Streams for Coal-desired Fuels. (Pittsburgh Energy Research Center). pp 341-347 of Carcinogenesis: a comprehensive survey. (1976).

This summary indicates the extensive role that mass spectrometry is now playing in the analysis of coal hydrogenation and coal gasification products. Many of the techniques required can be carried over from established methods for the analysis of petroleum products. Major deficiencies in the above-described analytical scheme, wherein mass spectrometry could play a major role in the future, include devising a routine technique for the analysis of the product oil to evaluate operating parameters, and expanding research to devise techniques for evaluating environmental concerns.

Stryker, S.; B. Spewak. Interagency Energy/Environment R and D Program. (Environmental Protection Agency, Washington, D.C. (USA). Office of Research and Development). Mar 1977. p. 22.

EPA, in its role as coordinator of the Federal Interagency Energy/Environment R and D Program, will continue to work toward increased domestic energy development within acceptable social, economic, and environmental limits; promote coordination and communication among researchers and managers in all participating agencies; employ a simple, common sense R and D planning structure; carry out policy recommendations of the Interagency Task Forces; and schedule energy/environment R and D to support development of the domestic coal reserve as quickly and cleanly as possible.

Szuba, J. Study on Increasing Energy Effectiveness of Hard Coals Utilization. (1977).

The growing energy needs of the country require a new look at coal utilization as a fuel with enhanced efficiency. The complex schemes of hard coal processing presented assure the achievement of electric and thermal energies with the highest efficiency by utilizing liquid, gaseous and solid improved fuels. The schemes secure also the needs of chemistry.

Van Hook. R.I. Potential Health and Environmental Effects of Trace Elements and Radionuclides From Increased Coal Utilization. (Oak Ridge National Lab., Tenn. (USA)). Apr 1978.

A summary of our current understanding of health and environmental effects of trace and radioactive elements released during coal mining, cleaning, combustion, and ash disposal is presented. Physical and biological transport phenomena which are important in determining organism exposure are also discussed. Biological concentration and transformation as well as synergistic and antagonistic actions among trace contaminants are discussed in terms of their importance in mobility, persistence, availability, and ultimate toxicity. The consequences of implementing the President's National Energy Plan are considered in terms of the impact of the NEP in 1985 and 2000 on the potential effects of trace and radioactive elements from the coal fuel cycle. Areas of needed research are identified in specific recommendations.

COAL-GENERAL INFORMATION

. 172nd National Meeting of the American Chemical Society, Division of Fuel Chemistry, San Francisco, California, August 29-September 3, 1976. Chicago; American Chemical Society (1976). p. 195.

Separate abstracts were prepared for each paper. (LK)

. First Rocky Mountain Fuel Symposium. Proceedings of a Conference Held January 30, 1976, in Provo, Utah. (Brigham Young Univ., Provo, Utah (USA)). 30 Jan 1976. p. 12. TIC.

This symposium brought together top technical experts in the intermountain area to present and discuss data concerning coal, gas, tar sands, and oil shale. This compilation includes abstracts only of 27 papers. Two papers were given in the General Session on in situ experiments at the Laramie Energy Research Center and on overburden handling at surface coal mines. Session A entitled: Gasification, In situ Recovery and Related Studies, contained 12 papers, most relating to in situ recovery. Session B, Fossil Fuel Liquids, Combustion of Fossil Fuels, and Catalyst Studies, contained 13 papers, most of the papers relating to coal analysis, combustion, processing, etc. (MCW)

. International Energy Agency: Coal Research. (Dec 1976).

Agreements signed last year by countries participating in the International Energy Agency's coal technology working group set up five major research projects. One is the Grimethorpe fluidized bed programme. The other four are service projects, mainly to collect and coordinate information available from a wide variety of sources. They are the data bank of world coal reserves and resources, the technical information service; the economic assessment service, and the mining technology clearing house service.

. Iowa Coal Research Project. Interim Report. (Iowa State Univ. of Science and Technology, Ames (USA). Energy and Mineral Resources Research Inst.). 15 Jul 1976. p. 30.

Recent accomplishments of the Iowa Coal Research Project are described. Planning for the final year of the three-year appropriation period is included. Mining of the ISU Demonstration Mine No.1, started in July 1975, will be completed by June 1977; restoration and environmental studies will continue at that site for

another three years. The coal preparation facilities (beneficiation plant), dedicated and started up in May 1976, will have completed production-quantity test runs on various Iowa coals by June 1977. A process cost analysis will be released this fall. Laboratory-scale equipment for processing studies of coal and coal fines will be installed and preliminary evaluation research will be conducted. An economic assessment of the Iowa coal industry has been completed and published; additional studies, refinements and updating of this assessment will provide a supplemental report available by July 1977. Transportation research (started this spring) will be incorporated into this supplemental assessment. Additional reports which will be published by June 1977 include: a study of ownership rights to mine coal and a rather complete identification of all coal mines operated in Iowa in the last century; a mining law handbook describing problems and giving information on regulations, taxes, legal considerations, and safety and health rules; and economic studies of mining and land restoration costs, coal processing costs and transportation costs in which comparisons will be made between different equipment, methods and systems.

Kentucky Energy Resource Utilization Program.
Semi-annual Report 1 Jan-30 Jun 1976. (Kentucky Univ., Lexington (USA). Inst. for Mining and Minerals Research). Aug 1976. p. 72.

This report describes progress on the various projects comprising the research and development component of the Kentucky Energy Resource Utilization Program during the six-month period from January 1, 1976 through June 30, 1976. The work described is an extension and expansion of the program undertaken by the Institute for Mining and Minerals Research during the 1972-1974 biennium and expanded in the 1974-1976 biennium. (GRA)

Proceedings of the Fuel Switching Forum. (Mitre Corp., McLean, Va. (USA). METREK Div.). Nov 1977. p. 294.

Papers were presented at the forum on coal firing, environmental effects of coal combustion, boiler conversion from oil to coal, coal and ash handling, coal supply and transport, and coal burning equipment. A separate abstract was prepared for each paper. (JRD)

Fourth Symposium on Coal Utilization. (National Coal Association, Washington, D.C. (USA); Bituminous Coal Research, Inc., Monroeville, Pa. (USA)). 1977. p. 349.

The "Fourth Symposium on Coal Utilization" was sponsored by the National Coal Association and Bituminous Coal Research, Inc. and held at the Kentucky Fair and Exposition Center, Louisville, KY, Oct 18-20, 1977. Twenty papers have been entered individually into EDB and ERA, and 5 also into EAPA. Papers are mainly involved with

air pollution control, specifically sulfur dioxide control, by flue gas desulfurization, use of low sulfur coal, coal preparation, blending, etc. In addition there are papers on forecasting coal demand, coal markets, coal transport, trace elements in coal (and in ashes and air pollution), waste disposal, coal-in-oil mixture, and retrofitting. (LTN)

. Report on Potential for Increased Use of Coal in New England. (New England Federal Regional Council (USA). Coal Committee). Sep 1976. p. 129.

The use of coal in New England in order to help alleviate the problem of using imported petroleum was investigated by the New England Federal Regional Council's Energy Resource Development Task Force. The main concern was whether coal can be utilized economically in compliance with environmental standards. Twenty-seven conclusions and attendant recommendations are presented, the final one stating that coal is the only alternative to nuclear power in New England. Possible program and strategies with an elaboration of cost/benefits of increased coal use are summarized. (MCW)

. Inventory of Energy Research and Development: 1973-1975. Volume I, Serial U. Part I. (Oak Ridge National Lab., Tenn. (USA)). Jan 1976.

This inventory provides an overview of the R and D being performed in every aspect of energy exploration, production, distribution, use, and conservation. A brief introduction discusses the aims, history, scope, and design of the inventory. The main body of Volume I, Part I is devoted to bibliographic entries (including abstracts) concerning coal, petroleum, natural gas, and oil shales and tar sands. This inventory expands and updates two earlier inventories of ongoing energy research published in March 1972 and January 1974.

. Coal Technology Program, Annual Interim Report for Fiscal Year Ending June 30, 1976. (Oak Ridge National Lab., Tenn. (USA)). Oct 1976.

ORNL's progress in coal research programs is reported: coal gasification and coal liquefaction (hydrocarbonization), residue carbonization, solids removal from coal liquids, pyrolysis, in situ gasification, Synthoil process, analytical chemistry (of by-products, effluents, etc.) environmental effects (including study of carcinogens, mutagens, etc.), trace elements, materials technology, nondestructive testing, clinical research, and possible applications of process heat reactors. (LTN)

Coal Technology Program. Quarterly Progress Report
for the Period Ending September 30, 1976. (Oak Ridge National
Lab., Tenn. (USA)). Jan 1977. p. 188.

This quarterly report covers the progress made during the period July 1 through September 30 for the Oak Ridge National Laboratory research and development projects that are carried out in support of the increased utilization of coal as a source of clean energy. These projects are supported by the ERDA Divisions of Coal Conversion and Utilization, Fossil Demonstration Plants, Fossil Energy Research, Physical Research, and Biomedical and Environmental Research, and by the EPA Office of Research and Development through interagency agreement with the ERDA. The report is divided into the following sections: Hydrocarbonization Research and Residue Carbonization Projects; Supporting Research and Development in Separations Technology; Experimental Engineering Support of an In Situ Gasification Process; Coal-Solvent-Hydrogen Mixing; Materials Technology; Chemical Research and Development; Alkali Metal Vapor Topping Cycles; Critical Components Test Facility; Engineering Studies and Technical Support; Process and Program Analysis; and Life Sciences Program Synthetic Fuels.

Coal Technology Program Quarterly Progress Report
for the Period Ending December 31, 1976. (Oak Ridge National Lab.,
Tenn. (USA)). Apr 1977. p. 209.

This quarterly report covers the progress made during the period October 1 through December 31 for research and development projects carried out in support of the increased utilization of coal as a source of clean energy. These projects are supported by the ERDA Divisions of Coal Conversion and Utilization, Major Facility Project Management, Materials and Exploratory Research, Physical Research, and Biomedical and Environmental Research, and by the EPA Office of Research and Development through interagency agreement with the ERDA. The report is divided into the following sections: hydrocarbonization research; residue carbonization; engineering support of in situ gasification; alkali metal vapor tapping cycles; materials and components testing (especially pressure wrench and pipe and nondestructive testing); analysis of processes and programs; chemical research and development; environmental effects and biological effects of by-products, liquid and gaseous wastes, etc. (LTN)

Coal Technology Program. Quarterly Progress Report
for the Period Ending March 31, 1977. (Oak Ridge National Lab.,
Tenn. (USA)). Jul 1977. p. 192.

Two-dimensional pyrolysis behavior of an eastern bituminous coal has been studied using slow heating rates and maximum temperatures ranging from 600 to 1000°C. Significant swelling has been observed, especially at lower heating rates, and gas production has been erratic. Chars produced have been singularly unreactive and possess considerable crushing strength, in direct contrast with those obtained from western subbituminous coals which were pyrophoric and extremely friable. All process equipment and instrumentation for investigation of the pressurized carbonization of Consol synthetic fuel residue has been installed and four experimental shakedown runs have been made. Tests on the gas-fired potassium boiler using water as a stand-in for potassium have been completed. We are conducting a design study of a coal-fired alkali metal topping cycle and conventional steam bottoming cycle to establish a reference design for a 200-MW(e) utility module. We completed the compilation of physical and thermodynamic properties of cesium and potassium, the analysis of a series of cesium and potassium turbine designs, and the determination of the cycle efficiency for both fluids for a variety of operating conditions. Several activities are in progress for nondestructive examination of wear-and process-resistant coatings. A new x-ray fluorescence system has been installed. Radiography has proved useful in monitoring the condition of tensile-cracked surface-defect specimens at various stages in the cracking process. Thermal testing has successfully detected unbonds in ZrO₂-coated specimens. Calibration continues on the eddy-current instrument to measure ceramic coating thickness. Useful results with a new and unusual liquid penetrant formulation were demonstrated. The deposition of alloy 320 cladding on low-alloy steels has been studied experimentally using the gas metal-arc and submerged-arc processes. (LTN)

Coal Technology Program Quarterly Progress Report
for the Period Ending June 30, 1977. (Oak Ridge National Lab.,
Tenn. (USA)). Oct 1977. p. 253.

Results of ORNL's research efforts in the following areas are described: Mock-up experiments, hydrocarbonization, carbonization of residues, engineering support of in situ coal gasification, pressurized carbonization, coal-solvent-hydrogen mixing, mathematical models of coal conversion processes, synthetic fuels process research digest, industrial coal conversion equipment capability, large oxygen plant feasibility study, heat recovery processes, hot-gas purification, flash hydrolysis, comparative evaluation of low Btu gasification process, coal combustion, advanced power conversion systems, evaluation of coal liquefaction processes, high

Btu gasification processes, fuel gas purification, coal prices and transport charges, environmental effects of natural gas pipelines, environmental monitoring handbook, materials technology, alkali metal vapor topping cycles, coal-fired alkali metal power systems, equipment tests and test facilities, chemical research and development, air and water pollution and pollutant transport from coke ovens, etc. (LTN)

. Meeting Report: Advanced Fossil Fuels Sector Group, Las Vegas, 25 August 1976. (Stanford Research Inst., Arlington, Va. (USA)). Oct 1976. p. 122.

The general areas of concern were: Advanced oil processing; Chemical coal cleaning; Synthetic fuels environmental assessment; Synthetic fuels control technology development; High temperature/high pressure particulate treatment; Environmental processes and effects.

. Statement of Capabilities and Commitments for Cooperation in the Establishment of a U.S. Bureau of Mines Research Station at Carbondale, Illinois. (Southern Illinois Univ., Carbondale (USA)). 1975. p. 86.

Illinois is firmly committed to the development of coal, the State's most abundant mineral resource. To help realize its potential, Southern Illinois University (SIU) at Carbondale has received approval from its Board of Trustees and the Illinois Board of Higher Education to develop a Coal Extraction and Utilization Research Center. In its formative stages, the center will investigate and research aspects of coal extraction. Although specific interests include research on extraction techniques, miner health and safety provisions, land reclamation, and subsidence control, efforts have been made to more broadly define the goals of the university's programs. Realizing that Illinois is a major exporter of goods, including coal, the programs being developed will emphasize the state's national geographic and commercial position as well as the state's economic and energy needs. To assist in the achievement of these goals, this booklet proposes a cooperative venture between the Southern Illinois University Coal Extraction and Utilization Research Center and the U.S. Department of the Interior to establish a new Bureau of Mines research station in Carbondale.

. Conference on Materials for Coal Conversion and Utilization. (Energy Research and Development Administration, Washington, D.C. (USA)). Mar 1977. p. 127.

From Conference on Materials for Coal Conversion and Utilization; Germantown, Maryland, United States of America (USA) (30 Sep 1976).

. 1979 Department of Energy Authorization. Volume II. Fossil Fuels Research. Hearings Before the Committee on Science and Technology, U.S. House of Representatives, Ninety-Fifth Congress, Second Session. Washington, DC; Committee on Science and Technology (1978). p. 733.

The Subcommittee of Fossil and Nuclear Energy R, D, and D met on Jan. 26, 1978, to begin the hearings on the 1979 authorization budget for fossil-fuel research. The hearings were structured around the near-term fossil-energy program. Energy conservation was cited as the main thrust of the short-term mitigation with alternative fuel resources being developed to the limit, especially coal. The organizing of the Office of Energy Research and the accomplishments to date in that office are reviewed. Dr. Eric Willis reviewed DOE's overall thinking on fossil technology and Mr. George Fumich discussed that budget. Dr. W. B. Harrison, Sr., talked about large coal-burning electric utility systems, particularly the SRC process, which he prefers over coal-derived liquids or flue-gas desulfurization. Michael D. Dingman presented written testimony supporting SRC-fired plants while William F. Morse reported on the potential of Devonian shales. On Jan. 31, testimony concerned coal conversion, oil shale, and coal mining R and D. On Feb. 1, Dr. Richard A. Flynn reported that the SRC-II process had been operating successfully for a year at the Fort Lewis Pilot Plant using Kentucky coal, but that Illinois No. 6 and Pittsburgh seam coal were acceptable. Other witnesses spoke on Hy-gas and U-gas processes, Devonian shales, peat deposits, advanced power systems, fuel cell and gas-turbine power plants, coal gasification combined-cycle program, and specifically, the Powerton Gasification Combined Cycle Test Facility. The Feb. 9 testimony dealt with the impact of the draft standards of performance for utility boilers on new and developing energy technologies. (MCW)

Anderheggen, E. Robens Coal Science Lecture, 1976: International Co-operation in Coal Research. 25 years' Personal Experience. (Mar 1977).

The phases in development of international cooperation in coal research are discussed. Problems and difficulties resulting from the different geological and economic conditions affecting the coal mining industries in the different countries are analyzed and are discussed in relation to how they affected the development of international cooperation. The development of international co-operation in coal research in the last 25 years is traced beginning with a description of the conditions in countries of the European Community where international cooperation began. A few personal remarks of the author completes the paper. (BLM)

Balzhiser, R. Coal: the R and D Pivot for New Energy Fuels, Cycles, and Storage. (1977).

The Electric Power Research Institute (EPRI), after three years of coal research, has already produced results that make coal operations more efficient and less damaging to the environment. Growing demands for electricity will require increased use of coal, our most abundant energy source. Research to improve plant performance, increase environmental control, and make end uses of electricity more efficient are needed. An EPRI analysis of ten options for coal concluded that direct-fired, low-sulfur coal offers the lowest busbar cost, followed by direct-fired, high-sulfur coal. Combined-cycle systems promise to be competitive after 1985. EPRI's efforts have included work on controlling finer particulates, improving fabric filters, scrubbers for sulfur oxides, assessment of sludge regeneration, and control of nitrogen oxides. Other studies are under way to find better ways of using water, cleaning coal, demonstrating conversion alternatives such as fluidized-bed power plants, design and engineering problems of power plants, and different forms and uses of coal. Solar demonstration projects, geothermal and fusion research, energy storage, and conservation strategies are all part of ERPR's commitment to the utilities. (DCK)

Brown, A. Jr. General Motors Powdered Coal-Oil Mixture Program. Feb 1977.

With the current emphasis on lessening the dependence on foreign oil by converting all oil-fired steam generating facilities to coal, the nation faces large capital expenditures. An alternative that directly attacks this problem is pulverized coal-in-oil. In this approach, oil supplies are extended through the partial substitution of coal. Coal-oil mixtures are manufactured by first pulverizing coal to 70 percent through 200 mesh, then mixing it in No. 6 residual fuel oil. This mixture can be used in a boiler as is or with an additive. It has been estimated that the successful implementation of coal-oil mixtures can have a potential impact equivalent to 30 percent of the imported oil to the United States. This would be equal to the annual fuel consumption of 36 million cars. In addition, implementing time is only one year compared to the three- to four-year lead time required for new coal-fired boilers. The benefits to the United States of using coal-oil mixtures are: extension of fuel supplies for transportation, chemical and home use; expanded use of coal; minimal capital expenditure; operating cost savings; and versatility of operation.

Decora, A.W. Internal Quarterly Progress Report, April--June 1976.
(Energy Research and Development Administration, Laramie, Wyo.
(USA). Laramie Energy Research Center). Jul 1976.

Coring of the test interval at LERC's Tar Sand Recovery Site was completed. Tar sand intervals above the test zone were also cored in an attempt to locate another suitable zone for the second field experiment. Core analysis indicates that a suitable zone is not present above the first test interval. A well has been drilled south of the first test pattern. Core analysis has been completed, and air-injection tests are being conducted. Kinetic data obtained on five whole tar sands indicate a first order reaction for bitumen pyrolysis. The apparent activation energies for all five samples are similar, suggesting similar reactivities and pyrolysis pathways. Successful ignition and operation of the in situ oil shale experiment at Rock Springs site 9 continued during this quarter. In research supporting the in situ field experiments on oil shale, bench-scale studies and one test in the 10-ton retort were completed as part of a program designed to provide comprehensive data for resolution of temperature anomalies previously observed during retorting tests of large oil shale blocks. Results indicate that the formation of secondary thermocouple junctions give rise to the anomalous and erroneous temperature measurements. Thirty-four retort runs were completed on various phases of gasification of oil shale. Routine water sampling at Site 9 and in the Upper Green River Basin wells was continued. Retort studies at Anvil Points this quarter consisted of completing retorting runs with conditions that would provide required data points for a commercial design. In studies on the underground gasification of coal, the reverse combustion link from Well 5 to 6 followed by forward gasification from Well 6 to 5 was completed with successful results. In addition, the reverse combustion link from the 56 line to the 78 line was completed. (JGB)

Field, J.H.; R.T. Eddinger, Ann Arbor. 167th National Meeting of the American Chemical Society, Division of Fuel Chemistry, Los Angeles, California, 31 March 1974-5 April 1974. Volume 19, No. 2. MI;
Xerox University Microfilms (1974). p. 338.

Abstracts were prepared for three papers presented at the Symposium on Low-sulfur Fuels from Coal: Part II. Abstracts were prepared for twenty-one papers presented at the Symposium on Shale Oil, Tar Sands, and Related Fuel Sources. (JGB)

Flock, D.L. Provincial Resource Development Research Policy. (Univ. of Alberta, Edmonton). (1976).

In Alberta, there is an abundance of oil, natural gas, and coal. But only a small portion of the Alberta oil sands and coal resources are commercially accessible to surface-mining techniques. It is quite apparent that some in situ technological breakthrough will be required, which will mean a concerted research effort at

the provincial level. It is the purpose of this paper to present certain concepts and recommendations for a coordinated provincial resource development research policy for the Province of Alberta. Research as discussed in this paper covers basic and applied research and development. (MCW)

Keil, G; H. Klare. Use of Coal as a Raw Material and as an Energy Source. Koks, Smola, Gaz; 22: No. 10, 245-248 (Oct 1977). (In Polish).

Present trends in the use of energy carriers are discussed, special attention being paid to hard coal. New methods are suggested of using coal as an energy carrier and as a raw material.

Kershaw, R. Coal Research Concentrates on Byproducts. Glueckauf; 113: No. 3, 134-135 (Feb 1977). (In German).

A report is presented on R and D projects of the National Coal Board (NCB) with the objective of a better utilization of coal as a chemical raw material and as an energy source.

Matthoefer, H. Research for Coal. (Bundesministerium fuer Forschung und Technologie, Bonn (German, F.R.)) Bergbau; 27: No. 5, 141-143 (May 1976). (In German).

The Federal Minister of Research and Technology, Matthoefer, voices his opinion on the role of coal in the energy program.

Meissner, C.R. Jr.; C.B. Cecil, G.D. Stricker. Coal Geology and the Future. Symposium Abstracts and Selected References. (eds.). (Geological Survey, Reston, Va. (USA)). 1977. p. 24.

This symposium, sponsored by the U.S. Geological Survey, was held in Reston, Va., September 27-28, 1976. The primary purpose of this meeting was to identify present and future geological research requirements in coal exploration, mining, and utilization in response to the ever-expanding demand for coal to meet the Nation's energy needs. In order to accomplish this objective, leading research scientists from State and Federal agencies, industry, and universities were invited to present results of their investigations emphasizing problem areas and further research needs. The abstracts, with selected references, included in this circular should serve as a valuable summary and reference source for those who wish to pursue any or all facets of the topics covered. The program was structured to encompass both theoretical and applied geological research from the origin of coal to ultimate utilization. The first technical session considered the general geology of coal from the peat-forming environment through the genesis of bituminous and anthracite coal. The second session was devoted to geology as applied to coal exploration, coal mining, and reclamation of mined land. Geological science as applied to utilization of coal in the generation of electricity, coke manufacture, gasification, and liquefaction was the focus of the third session. Finally, the various programs in coal geology of the U.S. Geological Survey (U.S.G.S.) were considered.

Murray, D.K. Geology of Rocky Mountain Coal. (ed.). (Colorado Geological Survey, Denver (USA)). 1977. p. 184.

Papers and abstracts of papers are presented concerning coal petrology, coal stratigraphy, Wyoming coal deposits, Montana coal deposits, logging, degasification of coal deposits and coal composition. Fourteen of the papers were processed individually. (JRD)

Peters, H.M.; D.S. Ross. Preprints of the 1976 Coal Chemistry Workshop. (eds.). (Stanford Research Inst., Menlo Park, Calif. (USA)). 15 Nov 1976. p. 244.

Twenty papers were abstracted and indexed separately. Abstracts of 8 additional papers are included in the compilation.

Seamans, R.C. Jr. ERDA's Coal Program for Combustion, Liquefaction, MHD, Gasification. (Energy Research and Development Administration, Washington, DC). Prof. Eng. (Wash., D.C.); 46: No. 4, 21-23 (Apr 1976).

Coal production in 1975 increased only six percent, while consumption increased only two percent. Between now and the year 2000, coal will play an increasingly critical role. Beyond that time, its contribution will continue to be important, but other energy sources should gradually shoulder the burden of supplying most of our energy needs. The key to increased coal production lies in finding technologically superior ways to mine, transport, and utilize coal--ways that are economically competitive with alternative sources (particularly oil and gas) and environmentally acceptable. ERDA's coal-related energy R and D program is designed to address major technological problems slowing down the large-scale utilization of coal. ERDA's coal program comprises essentially five categories: (1) direct combustion, with primary emphasis on the fluidized bed combustor; (2) liquefaction of coal into low sulfur boiler fuel and possibly to gasoline; (3) gasification of coal into high- and low- Btu gas for pipeline and boiler use, respectively; (4) deposits; and (5) advanced power generating systems such as magnetohydrodynamics (MHD). The Federal budget for ERDA's coal programs has leaped from \$65 million in 1974 to a proposed \$389 million in 1977. The largest portions of the 1977 budget are allocated for gasification, liquefaction, and direct combustion. (MCW)

White, P.C. Alternate Fuel Sources: ERDA Research Program. (Energy Research and Development Administration, Washington, DC). (1976).

The United States is dependent on petroleum and natural gas for 77% of its total energy consumption. The economy is geared to function on liquid and gaseous fuels while the supply of naturally occurring hydrocarbons is steadily decreasing. Projections show that at current consumption levels the U.S. supply will run out within

the next forty years. While the production of oils and gas can be increased through the application of secondary and tertiary recovery techniques, this will only stretch the U.S. resources by ten years. The Energy Research and Development Administration has developed a research, development and demonstration program aimed at developing alternative energy sources. One of the major programs is aimed at converting the vast coal reserves into more usable forms through coal liquefaction, high and low Btu gasification, and better methods of burning coal in its solid form. In addition, more advanced energy systems such as magnetohydrodynamics are being developed. The successful development of coal conversion technologies will allow the necessary time to develop inexhaustible sources of energy such as the nuclear breeder and solar energy.

White, P.C. Fossil Energy Research Program of the Energy Research and Development Administration, FY 1978. (Energy Research and Development Administration, Washington, D.C. (USA)). Apr 1977. p. 378.

The Fossil Energy (FE) Research, Development, and Demonstration (RD and D) Programs of the Energy Research and Development Administration (ERDA) are expanding in response to the national need to develop adequate amounts of clean fossil fuel from domestic resources. The need for these programs and their relationship to other energy research efforts were contained in ERDA-48, A National Plan for Energy Research, Development, and Demonstration, released in the summer of 1975, and in ERDA-76-1, A National Plan for Energy Research, Development, and Demonstration, released in early 1976. The update of the National Energy Plan was to be available early in 1977. The purpose of this report is to provide additional details on the projects underway and planned in FE, with specific emphasis on the President's FY 1978 Budget Request. The research documented in this report is guided by the following overall program goals: to develop the technology needed to make fossil fuels available in the form and quantity needed and to assure that the Nation's fossil fuels resources are developed at acceptable economic, social, and environmental costs. These major goals have been translated into funding requirements for each of the programs.

Yen, T.F. Shale Oil, Tar Sands, and Related Fuel Sources. (ed.). Washington, DC; American Chemical Society (1976). p. 190.

Fourteen papers were presented at the symposium on oil shales, oil sands, desulfurization, chemical modification of bitumens, coal hydrocracking, and ozokerites. A separate abstract was prepared for each paper. (JRD)

COAL GASIFICATION-ECONOMICS

Research and Development on Steam Gasification of Coal. Status Report at end of Concept Phase, August 1, 1975--November 30, 1976. (Bergbau-Forschung B.m.b.H., Essen (Germany, F.R.)). Dec 1976.

The plant designed for coal gasification with steam is connected to a high-temperature reactor (HTR) and operates at 40 bar pressure. Various processes known from conventional gasification technology were adapted on a case by case basis to the requirements of a combined nuclear plant and gasification installation and optimized. The resulting gas generator is an entirely new development in which the nuclear reactor-heat is transferred via a pipe heat exchanger with circulating helium to a fluidized bed of coal and steam. Its key problems are the development of a suitable material for the heat exchanger and the determination of reliable data for the sequence of and products of gasification with regard to the total planning concept. According to the material study, there are already materials which can be used for a sufficiently long period in the gas generator. The data about the reaction rate, heat requirement, fluidized bed density and heat transfer from the heat exchanger to the fluidized bed needed to determine the gasification data were measured in the laboratory and in a small-scale, kg-sized plant. Besides the use of steam as gasifier, studies were performed using mixtures of steam and hydrogen. The latter are of particular importance to hydrogenation in combination with the steam gasification of coal. It is of great importance to the transferability of the results to large-scale plants that the tests were performed with semi-commercial equipment in which the gasification was performed in a section of the large-scale gas generator with heat introduction from the helium circuit.

High Mass Flux Coal Gasifier. Quarterly Technical Progress Report, May 1976--August 1976. (Bell Aerospace Textron, Buffalo, N.Y. (USA)). 1976. p. 38.

The feasibility of using a High Mass Flux gasifier (greater than or equal to 20,000 lb/hr-cu ft) for generating low BTU gas, using a reactant combination of coal/air, is being explored. The technical progress during the second reporting period of the eight-month program is summarized. Test facility checkout and calibrations were completed. A gasifier initiation sequence using a solid grain propellant charge was defined and demonstrated. Performance evaluation tests for different injector configurations, over a range of air/coal mixture ratios, were initiated. Five injector configurations were evaluated during the reporting period.

. Study to Assess the Application of Shadow Pricing Techniques to National Energy Resource Planning. Year I Final Report. (Brookhaven National Lab., Upton, N.Y. (USA)). Jun 1976. p. 158.

A Dynamic Energy System Optimization Model is described that can analyze optimal allocation of exhaustible energy resources over time. It is a multi-period representation of the nation's energy supply and utilization system that incorporates cost and time elements associated with new capital facilities, the discount rate, internal selection of new energy technologies, and internal determination of primary energy resource allocation over time. Two demonstration applications of a single-period energy model are also presented. The first estimates benefit/cost ratios for Federal R and D investment in high-Btu coal-gasification technology. The second evaluated the economic impact of a sulfur dioxide emission constraint in certain end uses.

. Third Annual Energy Report, 1977. Des Moines; Iowa Energy Policy Council (1977). p. 73.

A compilation of energy data for the state of Iowa is published for use in considering energy matters. Included is information about the historic use and distribution of energy in Iowa, the growth rate of energy consumption in Iowa, a projection of energy consumption trends in Iowa for the next ten years, assessments of the impact of meeting those needs on the economy and the environment of the state, evaluations of alternative sources of energy, and of the feasibility of coal gasification. A statement of the Council's energy conservation policy, together with a plan to carry out that policy, is a part of this report. There also are subjects suggested for legislation which, in the Council members' judgment, would help bring about this energy conservation plan.

. Economics of Air vs O₂ Pressure Gasification of Coal. Report on Phase I. (Fluor Engineers and Constructors, Inc., Los Angeles, Calif. (USA)). Jan 1975. p. 204.

Directional economic trends for the alternative use of air or oxygen in coal gasification processes are studied. The processes evaluated are: moving bed, fluidized bed, and entrained bed gasification to produce clean fuel gas. In addition, entrained bed coal gasification is studied in conjunction with a combined cycle power plant. (GRA)

. Nuclear Process Heat (VHTR) Commercialization Study. Volume I. Final Report. (General Atomic Co., San Diego, Calif. (USA)). Dec 1977. p. 132.

This report presents the results of a study performed for the Department of Energy to determine the appropriate place in the commercial market-place for a very high temperature reactor (VHTR) providing heat for the gasification of coal. A description

of the VHTR and the processes used for the gasification of coal to produce substitute natural gas, synthesis gas, and hydrogen, along with costs, is supplied as well as is a process for providing thermal energy via a pipeline over long distances using a reversible chemical reaction. The resulting cost for substitute natural gas (SNG) was compared with the fossil-fired HYGAS process and proved to be more economical.

. Market and Economic Analysis Study on Nuclear Coal Gasification. Status Report at end of Concept Phase, August 1, 1975--November 30, 1976. (Germany, F.R.); Jul 1978. p. 108.

The present study has as its objective a determination, based on the state of technical knowledge attained in the concept phase of the PNP project, as to whether the potential usage and the economic prospects of nuclear coal gasification will justify the high development expenses which would be involved. Synthetic natural gas (SNG) was considered as the product of the nuclear coal gasification. The investigations on the potential usage of SNG concentrated on the heating market in the German Federal Republic, in consideration of the development expected to the year 2025. The gas production costs were determined for various nuclear gasification processes, and these were compared with those of the Lurgi pressure gasification as an example of conventional process, as well as with the price of heat from natural gas and light heating oil. The economic advantage in the operation of nuclear coal gasification was determined relative to petroleum and natural gas, and the development expenses were compared. However, no comprehensive cost/benefit analysis could be made within the limitations of the given time frame. The potential usage and the heating costs of long-distance nuclear energy were investigated in a separate section. In this system, the nuclearly generated heat is captured by the endothermic chemical reaction of reforming of methane with steam to produce a synthesis gas ($\text{CO} + \text{H}_2$). The chemically bound energy of the synthesis gas, which is transported coal over large distances, is then reliberated by the reverse, exothermic chemical reaction of methanization, and used. The system can be operated in a closed or open mode.

. Advanced Coal Gasification System for Electric Power Generation. Quarterly Progress Report, October 1--December 31, 1976. (Westinghouse Electric Corp., Lester, Pa. (USA). Generation Systems Div.) 25 Jan 1977. p. 80.

A unique coal gasification system employing multiple fluidized beds has been embodied into a process development unit located at Waltz Mill, PA. The two main process loops are at present arranged for independent operation. The devolatilizer/desulfurizer subsystem testing on coal was previously completed, after a 168 hour continuous run processing two highly-caking Pittsburgh seam coals. The gasifier/agglomerator subsystem was prepared for test operation and the first tests of this subsystem were conducted.

Bissett, L.A. Engineering Assessment of Entrainment Gasification. (Department of Energy, Morgantown. W.Va. (USA). Morgantown Energy Research Center). Apr 1978. p. 410.

This report represents the engineering assessment of entrainment gasification. The purpose of this study was to review the state-of-the-art and certain technical and economical aspects of entrainment gasification in order to provide guidance for its future development. The technical analysis was primarily accomplished by the use of a simple mathematical model. The economic analysis, for the most part, drew heavily on the results from two independent studies. Finally, certain observations and conclusions are listed, as well as suggested recommendations for future development work. The report generally concludes that, in relation to other gasification technologies, entrainment gasification is technically sound and economically competitive, and makes one set of recommendations associated with the operational aspects of large-scale development, and another set pertaining to further research and development efforts that could lead to improved gasifier performance.

Breyer, W. Marketing Chances and Economy of Nuclear Gasification of Coal to Synthetic Natural Gas (SNG). (Internationale Atomreaktorbau G.m.b.H. (INTERATOM). Bensberg/Koeln (Germany, F.R.); Gesellschaft fuer Hochtemperaturreaktor-Technik m.b.H., Bensberg/Koeln (German, F.R.)); Oesterwind, D. (Kernforschungsanlage Juelich G.m.b.H. (German, F.R.)); Wiegand, D.; Bode, K.H.; Schrader, L. pp 1011-1015 of In Reaktortagung, Mannheim, 29.3-1.4.1977. Sektion 9: Energie, insbesondere Kernenergie. Eggenstein-Leopoldshafen, Germany, F.R.; ZAED (1977). (In German)

4 figs.; 1 ref. Short communication only.

Chinnery, K.M. Higher Oil and Gas Prices Place Coal Gasification in New Light. (The Lummus Co. Canada Ltd., Willowdale, Ontario). (23 Sep 1976).

Although coal is our most abundant energy resource, it cannot be fully utilized in its natural form. By gasification, which is the controlled, partial oxidation of coal in steam and air or oxygen, coal can be transformed into more efficient, environmentally acceptable fuels and petrochemical feedstocks. Although the technical aspects of coal gasification have been known and demonstrated for a number of years, it has, with only a few exceptions, been performed on a much smaller scale than now required. Modern gasification processes are environmentally sound and the product is clean, convenient and easily transportable, as compared to the coal itself which is dirty, inconvenient for many users and only transportable at considerable cost. The various processes under development have the objective of finding the most economic way of achieving the optimum reaction conditions with available construction materials and technology. Of the current gasification systems involving commercially proven equipment and operating methods, those likely to prove of particular interest in the immediate future are:

the Lurgi Gasifier and the Koppers-Totzek Gasifier. Research and development programs are now being conducted into second-generation gasifiers which are generally aimed at developing reactors that have higher capacities, can accept all types of coal and promote more extensive methane formation. Pilot plant testing on various systems is well under way, including gasification of fluidized coal under pressures in the order of 1,000 psi with oxygen and steam. Much attention is also being given to hydrogasification, gasification with hydrogen and steam, and improved methanation procedures.

Corneil, H.G.; F.J. Heinzelmann, E.W.S. Nicholson. Production Economics for Hydrogen, Ammonia, and Methanol During the 1980-2000 Period. (Exxon Research and Engineering Co., Linden, N.J. (USA). Government Research Lab.). Apr 1977. p. 178.

Refinery hydrogen, ammonia, and methanol, the principal industrial hydrogen products, are now manufactured mainly by catalytic steam reforming of natural gas or some alternative light-hydrocarbon feed stock. Anticipated increases in the prices of hydrocarbons are expected to exceed those for coal, thus gradually increasing the incentive to use coal gasification as a source of industrial hydrogen during the 1980 to 2000 period. Although the investment in industrial hydrogen plants will exceed those for reforming by a factor of 2 or more, coal gasification will provide lower production costs (including 20%/y before tax return) for methanol manufacture in the early 1980's and for ammonia 5 years or so later. However, high costs for transporting coal to major refining centers will make it difficult to justify coal gasification for refinery hydrogen production during the 1980 to 2000 period. By the year 2000, 40 to 50% of the U.S. industrial hydrogen requirements will be provided by coal gasification, thus conserving natural gas and light hydrocarbon feed stocks equivalent to about 600,000 B/D of crude oil. Electrolytic hydrogen production costs will be reduced by improved electrolysis technology such as the solid-polymer-electrolyte process. These improved processes will reduce electricity requirements by about 20%. Although the production cost, including return for electrolytic hydrogen, will continue to exceed those for reforming and coal gasification, the use of electrolytic hydrogen will be attractive for many small users when the new technology is available in the early 1980's. Electrolytic hydrogen, now about 0.7% of total U.S. industrial hydrogen requirements, will probably increase to about 1.2% of the total by the year 2000.

Delannoy, G. Future of Coal in the Energy Economy. Rev. Gen. Therm.; 16: No. 188/189, 627-632 (Aug 1977).

This paper discusses the roles of coal and oil and notes that coal is set to become the dominant fuel. It cites uses where coal and oil can replace one another (e.g., heating, steam production) and specific uses for coal. It also discusses the needs of the French iron and steel industries and the development (by Cerchar and Irsid) of new processes. Successful research on coal-derived products, e.g., methane from coal gasification, in situ gasification, and the production of petrol by hydrogenation is noted. The costs of these processes should eventually become economically viable. Uses of coal by-products and waste, e.g., carbon fibres, active carbon, and sintered and forged carbons are mentioned.

Detman, R.F. Preliminary Economic Comparison of Six Processes for Pipeline Gas From Coal. 1976.

Several new processes for conversion of coal to pipeline gas are under development in the Joint ERDA-A.G.A. Coal Gasification Program. The potential of these processes for producing pipeline gas more efficiently than those using existing technology has been predicted if their development is successful. An impartial analysis of these processes and a comparison with older technology is needed to evaluate their potential. An analysis will also provide indications of the order of magnitude of plant costs, raw material and water requirements, and problem areas that require attention in the process development of commercial plants. At this point in the development of these new processes, a conclusive comprehensive analysis is not possible. The pilot plants are just beginning operations or just completed operations to prove technical feasibility, but have not yet produced sufficient design data to firmly establish the process design of a commercial plant. Nevertheless, some preliminary indication of how these processes compare with each other and with the older technology is considered desirable. Therefore, Braun has undertaken the preparation of such a preliminary analysis on the basis of the best design information available. This design data was supplied by process developers from bench scale experimentation or computer models of their process based on both theoretical and experimental information. In some cases, pilot plant data have since been produced that approximate the predictions of the process computer models.

Detman, R.; R.O. Skamser. Procedures for Pricing Synthetic Pipeline Gas from Coal. (C.F. Braun and Co., Alhambra, CA). 1976.

In 1973, a task force of the National Gas Survey issued a report for the Federal Power Commission on the technology and economics of producing pipeline gas from coal. This technology is still under development in the joint US Energy Research and Development Administration, American Gas Association coal gasification program.

The accounting procedures described in the FPC report are widely accepted for computing gas costs, but the cost projections have become outdated by rapidly changing economic conditions. The rate of inflation has become so unpredictable since the report was issued that little reliability can now be placed on such cost projections. However, comparative economic analyses by those procedures are still valid when referenced to equipment costs obtained at a specific time. It is also necessary to adjust quoted equipment prices to reflect inflation taking place before or after the reference date for price information. The technology for coal gasification is better understood than it was in 1973 and it is now possible to apply more specific ground rules to the comparative evaluation of the various processes. It is the purpose of this paper to identify basic assumptions and design criteria which will provide a consistent basis for economic evaluation. Eventual issue of Gas Cost Guidelines is contemplated as a standard for obtaining the cost of gas for any process that makes pipeline gas from coal.

Durie, R.A.; I.W. Smith. Production of Gaseous and Liquid Fuels from Coal. (Commonwealth Scientific and Industrial Research Organization, North Ryde, Australia). pp 161-172 of In Australian Black Coal: its Occurrence, Mining, Preparation, and Use. Cook, A.C. (ed.). Woolongong. Australia; Australasian Inst. of Mining and Metallurgy (1975).

Australia has, and faces, a growing problem with regard to the ability to meet the demand for liquid fuels from indigenous petroleum resources. The position for natural gas is better, but there is no room for complacency. Since the coal resources are relatively extensive, interest in the prospect of producing liquid fuels from coal is increasing. The approaches to the production of gaseous and liquid fuels from coal are briefly reviewed and the present status of coal conversion technology is discussed. Many problems remain to be solved and it is estimated (in the USA) that another 8-10 years will be required before any of the processes for liquid fuel production are considered sufficiently efficient and viable to go to a demonstration plant. Coals represent complex feedstocks and the effects of variations in coal properties on oil-from-coal processes are not fully understood. The thermal efficiencies of various coal conversion processes are considered in relation to their impact on coal requirements. The production of Australia's present requirement for liquid fuels by the only commercial process in operation would require a four-fold expansion in the local consumption of coal. Any assessment of the suitability of oil-from-coal processes currently under development overseas for Australian coals and requirements must take heed of the differences in coal properties and motivation. The economic viability of processes for producing oil from coal will continue to be uncertain because of the large difference between the world price for crude oil and the actual production cost.

Eickhoff, H.G.; K. Kugeler. Synthesis of Hydrocarbons Using Coal and Nuclear Process Heat. (Kernforschungsanlage Juelich G.m.b.H. (F.R. Germany)). (Aug 1975). (In German).

An analysis of global petroleum resources and demand shows that the amount of petroleum products is sufficient to meet the requirements of the next decades. The geographical resources, however, could lead to problems of distribution and foreign exchange. The production of hydrocarbons with coal as basis using high temperature nuclear process heat has advantages compared to the conventional techniques. Next to the conservation of reserve fossil primary energy carriers there are advantages as regard prices, which at high coal costs are especially pronounced.

Fischer, D.D.; L.A. Schrider. New Promise for Underground Coal Gasification. Vol. 2. (Energy Research and Development Administration, Laramie, WY). pp 98-103 of In Coal processing technology. Laramie, WY; Energy Research and Development Administration (1975).

An experimental program on underground gasification of a western U.S. subbituminous coal has demonstrated that in situ gasification can satisfactorily supplement an aboveground gasification system. The various aspects to be studied were the following: (1) Use of natural coal permeability to enhance process control and to optimize gas production, gas collection, and coal utilization. (2) Use of air, oxygen-enriched air, or pure oxygen as the gasification agent to determine feasibility of upgrading the produce gas to pipeline quality. (3) The extent of environmental impacts due to underground coal gasification. (4) Feasibility of downhole monitoring for process control. (5) Techniques by which gas production rate and product gas heating value can be stabilized. (6) Isolation of parameters to which economic evaluation of in situ coal gasification is most sensitive. (7) Overall evaluation of in situ coal gasification as a viable energy recovery technique. (BJH)

Gambill, W.R.; C.C. Littlefield, R.H. Cooper, Jr., J.E. Jones, Jr. Exploratory Studies of the Application of Gas-cooled Reactors to Coal Conversion. (Oak Ridge National Lab., Tenn. (USA)). Jan 1977. p. 76.

An exploratory study was made of the technology and economics of coupling a very high temperature gas-cooled reactor (VHTR) to a variety of coal-conversion applications. It is concluded that nuclear steam reforming of light hydrocarbons for coal conversion could be a near-term alternative and direct nuclear coal gasification could be a future consideration. Thermochemical water splitting appears to be more costly and its availability farther in the future than the coal-conversion systems. An examination of the materials required in process heat exchangers is made. 46 references.

Gupta, R.S.; B. Bose. Techno-economic Aspect of Gas Production in Producer Gas Plant Based on Coal and Coke. (Kipper India Pvt Ltd., Calcutta). (Oct 1976).

The technology of producer gas has been revived after the oil crisis. Technically, it is a proven method by which the energy required can be achieved from the gas producers at 50% cost in comparison to oil today. The payback period of the plant is 24 to 30 months only. It is recommended that hot gas should be used where gas cleaning is not necessary and tar can be burnt along with the gases. For sophisticated uses cold and clean gas should be used.

Hellermann, E.; H. Osthof. Study on the Possibility of Exporting Coal Conversion Technologies. (Germany, F.R.). Dec 1975. p. 172.

A survey is presented on important methods for coal conversion. The main topics are gasification, liquefaction, coking, and flue gas cleaning. On the basis of economic characteristics countries have been selected that are potential importers of coal conversion plants. The worldwide demand for different processes is determined. Recommendations for further developments of these technologies are given.

Hoffmann, F. Research in Coal. Analyses of Economy. Developments in Australia and South Africa. New technologies of Electricity Generation. May 1977. (In German).

Conference papers on economic aspects of coal conversion, coal gasification and liquefaction in Australia and South Africa, as well as on coal and electric power generation are summarized. Also, the basic general report of the vice chairman of the NCB, N. Siddal, is dealt with, which was the first lecture held during the Third International Coal Research Conference in Sydney.

Jones, C.H.; J.M. Donohue. Comparative Evaluation of High- and Low-Temperature Gas Cleaning for Coal Gasification Combined Cycle Power Systems. (Stone and Webster Engineering Corp., New York (USA)). Apr 1977. p. 151.

The purpose of this screening study was to evaluate the incentives for developing hot gas purification technology for application to coal gasification-combined cycle power generating systems. The iron oxide process currently being developed by the Morgantown Energy Research Center for removal of hydrogen sulfide at high temperature (1,000°F) was selected for this study. Process and economic evaluations were performed for five different coal gasification schemes, i.e. air- and oxygen-blown dry ash, moving bed Lurgi gasifiers; oxygen-blown slagging, moving-bed gasification currently being developed by the British Gas Corporation; and oxygen- and air-blown two-stage entrained gasifiers proposed by Foster Wheeler. For each of the above gasification schemes, four complete system flowsheets were developed for converting Illinois No. 6 coal to electricity via combined cycle power generation. Two of these

processing schemes were based on high temperature iron oxide technology with gas turbine inlet temperatures of 1,950 and 2,400°F. The other two flowsheets for each gasifier incorporated the low temperature Benfield process with gas turbine inlet temperatures of 1,950 and 2,400°F. The results of this study indicate that there is a large economic incentive for developing hot purification technology for dry ash Lurgi gasification systems. For advanced gasification schemes such as the BGC clagger or the two-stage entrained gasifier, no incentive could be identified for the development of high temperature iron oxide gas cleaning technology. Major technical questions that were raised concerned problems associated with the regeneration of iron sulfide, the fate of trace contaminants such as ammonia and alkali metal vapors in the system as well as the ability to remove particulates from the gas streams both before and after contacts with the iron oxide absorption equipment.

Kellogg, M.W. Comparison of Flue Gas Desulfurization, Coal Liquefaction, and Coal Gasification for Use at Coal-fired Power Plants. Final Report. Houston, Tex. (USA)). Apr 1975. p. 158.

The report presents a technical and economic comparison of the use of flue gas desulfurization, coal liquefaction, and coal gasification as a means of preventing SO₂ emissions at coal-fired plants. The report assesses the status of technology, process complexity, process flexibility, environmental effects, installation difficulties, energy conversion efficiency, manpower requirements, and economics of each approach to controlling SO₂ as it would be applied to electric power plants. Three different flue gas desulfurization systems were evaluated as well as one coal liquefaction and one coal gasification processes. Two power plant cases are evaluated, an existing 500 MW plant operating at 60 percent load factor and a new 1,000 MW plant operating at 80 percent load factor.

Kimmel, S.; E.W. Neben, G.E. Pack. Economics of Current and Advanced Gasification Processes for Fuel Gas Production. Final Report. (Fluor Engineers and Constructors, Inc., Los Angeles, Calif. (USA)). Jul 1976. p. 255.

The major economic conclusions of this study can be derived from the data presented. For the moving bed gasification systems it is apparent that air blowing the gasifiers results in a significant decrease in both the capital requirement and the cost of services for producing clean fuel gas from coal over an oxygen-blown system. The situation is not as obvious in the case of fluidized bed technology. Within the accuracy of this study, it appears that the capital costs for air- and oxygen-blown systems are approximately equal, with a very slight edge for the oxygen-blown system. The same is true for the relative cost of services for the fluidized bed cases. The estimates for atmospheric pressure entrained bed systems indicate that capital costs will be higher for air blowing but that the fuel gas cost will be lower from the air-blown system than from the oxygen-blown plant. The reason is the relatively

large amount of byproduct electric power produced by the air-blown plant. Therefore, for the Entrained Bed cases, the cost advantage attributed to the air-blown system depends heavily on the value assigned to the byproduct electric power. As the value of electric power increases, the advantage for the air blown system will increase. For reasons given, the economic results presented must be used with the utmost caution.

Lamb, R.H. Evaluation of COED Char Gasification Using Rummel/Otto Gasifiers. (Energy Research and Development Administration. Washington, D.C. (USA)). 20 Sep 1976. p.18.

In September 1975, the Ralph M. Parsons company issued R and D Report No. 114 - Interim Report No. 1 concerning the conceptual design and economic analysis of a commercial complex producing oil and power via COED based coal conversion. The Parsons design used fluid bed gasifiers, or char burners, for gasification of COED char. The objective of this task assignment is to investigate the effects of substituting a Rummel/Otto gasification system for the fluid bed gasifiers in the Parsons design. Substitution of the Otto gasification system changes the capital costs and utility requirements for several of the plant units in the complex. The extent of the changes are tabulated. The net results are an increase in fixed capital investment from \$1,000,000,000, to \$1,011,000,000., and a reduction of exportable electric power from 827 MW to 817 MW. All other quantities, such as coal feed, oil and sulfur produced, working capital, and operating labor remain unchanged. Operating requirements for the gasifier were derived from data contained in an Otto Company brochure concerning gasification of brown coal at elevated pressure. The data so derived should be checked against experimental data on char gasification in an Otto unit when the information becomes available. The negative results of this study do not necessarily apply to direct gasification of coal in an Otto gasifier. The results only show that, in combination with the COED process, fluid bed gasifiers are more economical.

Lamb, R.H. Evaluation of the B and W Slag-bath Gasifier. Task Report For Task Assignment. (Iowa State Water Resources Research Inst., Ames (USA)). 19 Apr 1977. p. 29.

The report includes conceptual designs for the B and W gasifier including material and energy balances, a process flowsheet, equipment sizes and capital cost estimates. An optimum use for it would be in a Parsons oil-gas type plant. It has, therefore, been evaluated by comparing it as a substitute for the Parsons gasifier. The conclusions reached are that the process may be technically feasible but would not be competitive with some other processes with respect to economy and energy conservation. In view of the lack of advantages offered by the process and the lower energy conversion efficiency, no further work on the process is recommended.

Luettringhaus, G. Coal Gasification--Development Prospects and Problems. (Univ Koeln, Ger). Aug 1975. (In German).

Based on a survey of the arguments in favor of coal gasification, the market potential that could materialize for coal gas by the end of this century is examined. The present state of gasification technologies in the United States and the Federal Republic of Germany is described. Finally, an attempt is made to determine to what extent a 1974 economic study of coal gasification with the help of nuclear process heat has already been outdated because of changes that have taken place in the meanwhile.

Manthos, G.J.; E.E. Ellington. Evaluation of a High-pressure Saarberg/Otto Gasifier. (Purvin and Gerta, Inc., Dallas, Tex. (USA)). Jan 1977. p. 46.

The economic and technological aspects of synthesis gas production are analyzed for a high-pressure Saarberg/Otto coal gasification plant integrated with a 30,000 ton per day (T/D) Coalcon hydro-carbonization facility. It was assumed that the entire char output of the Coalcon plant (12,980 T/D) would be fed to the Saarberg/Otto gasifiers. Cost estimates and economic calculations were made for four cases of the conventional gasification, shift conversion and gas purification scheme representing variations in the operating severity of shift conversion and gas purification systems to tailor the synthesis gas to different downstream uses. An economic comparison with the better known Koppers-Totzek process was made for purposes of substantiation. The capital cost estimates include an allowance equal to 3 percent of total process unit investment for offsites that would be shared with the Coalcon plant. The intended use of the synthesis gas proved not to be a major factor in capital requirements or the cost of produced gas. Capital requirements ranged from a high of \$687 million to a low of \$664 million. A comparable size atmospheric Koppers-Totzek plant with downstream compression would require \$807 million. The 20-year average cost of synthesis gas ranged from a high of \$1.16/MCF to a low of \$1.10/MCF. On the same basis, Koppers-Totzek gas would cost \$1.32/MCF. The economics are somewhat hypothetical because no commercial, high-pressure Saarberg/Otto plant has been built. Developmental work on a high-pressure unit is now in progress in West Germany. The results will determine the direction of future work on this process.

Melquist, V.H. Economics of Coal Gasification. (Continental Oil Co., Ponca City, OK). pp 69-71 of In Coal Processing Technology. American Inst. of Chemical Engineers (1974).

Substitute gas is technically feasible, but it will be expensive. It may be necessary to gasify coal, but this should be done only to the extent necessary to supply clean fuel to residential customers and other unconvertible users. Direct combustion of coal should be used as much as possible to supply our energy needs.

Mills, G.A. Alternate Fuels From Coal. (Energy Research and Development Administration, Washington, DC). CHEMTECH; 7: No. 7, 418-423 (Jul 1977).

The author concludes first that processes for synthetic fuels, especially gas, are now available and operable but expensive. Second, that improvements at pilot plant scale offer improvements but of limited economic advantage, about 15%. Third, that the projected costs for these synthetic fuels are twice or even more of those for natural petroleum. Fourth, that the idealized chemistry of coal to synthetic fuels is such that the processes should not require the very expensive plant investment that accounts for the high projected selling price for synthetic fuels, and finally that ERDA-sponsored research is bringing forth new processes, promising improvements much greater than 15%. Two of these are the catalytic coal gasification and conversion of crude methanol from coal to high octane gasoline. It is doubtful, in the absence of national policy considerations, including security or embargo, that present synfuels processes are going to compete economically until year 2000. However, I think we will develop new processes, or make major improvements that can cut costs drastically and thus make synfuels from coal economically.

Papic, M.M. Technology and Economics of Coal Gasification. (British Columbia Research, Vancouver). Can J. Chem. Eng.; 54: No. 5, 413-420 (Oct 1976).

The best known commercial coal gasification processes which use oxygen (air) and steam as gasifying media are the gas producer process (normal pressure, fixed bed), Lurgi process (high pressure, fixed bed), Winkler process (normal pressure, fluidized bed) and Koppers-Totzek process (normal pressure, entrained). Fixed bed and fluidized bed processes are suitable for gasification of noncaking and weakly caking coals with high ash fusion temperatures (1200°C). The entrained system is suitable for gasification of any coal. Low-calorie gas (approximately 150 Btu/scf) can be produced by the gas producer, Lurgi and Winkler processes; medium-(approximately 300 Btu/scf) and high-caloric (approximately 950 Btu/scf) gas by any process. Lurgi and Koppers-Totzek processes are preferred processes for production of synthesis gas at the present time. The costs (\$/Btu) of production of low-caloric gas are the lowest followed by the medium- and high-Caloric gas costs. The costs of gas production from coal are mainly dependent on the efficiency of the gasification process, scale of operation, and the cost of fuel.

Pulsfer, A.H. Electrofluid Gasification of Coal With Nuclear Energy.
Fuel Process. Technol.; 1. (Jan 1978).

The energy required for gasifying coal with steam can be supplied by a h.t. nuclear reactor coupled to a fluidized bed gasifier either thermally or electrically via an electrofluid gasifier. A comparison is made of the economics of supplying energy by these two alternatives which demonstrates that electrofluid gasification using a h.t. nuclear reactor may in certain circumstances be economically attractive, while experiments in small scale electrofluid gasifiers indicates that the technology is feasible. Equipment, experimental work and results are reported.

Rensch, J.R. Coal Gasification. (Pacific Lighting Corp., Los Angeles).
pp 84-90 of In Energy technology III: Commercialization. Bethesda, MD; Governemnt Institutes, Inc. (1976).

Coal gasification provides one of the significant answers to the question of how we can best develop and use our existing domestic energy sources. In order to bring about the earliest commercial application of gasification technology, the nation must move ahead with full-scale gasification plants, using available technology that has been proved by commercial and demonstration plant applications. Concurrently, the development, testing and refinement of second-generation technology, now in the pilot-plant stage, should be given high priority to be ready for broad commercial application as we move into the 1990's. High-Btu synthetic gas is interchangeable with natural gas. This country's existing gas pipeline systems now provide a highly efficient method of transporting energy. Compared with generation of electricity from coal, gasification provides a more-efficient conversion process, requires a much lower capital investment to deliver the same amount of energy, and is environmentally attractive from an air-pollution standpoint. The pioneer WESCO gasification project in Northwest New Mexico (scheduled to be the nation's first large-scale commercial plant) has been held up by approval delays, and the cost of the first unit has escalated to over \$1 billion. Each day of continued delay adds \$220,000 to the cost of the project. Even with the higher cost, however, synthetic gas from this plant offers an attractive energy alternative for the consumer. With the Environmental Impact Statement now issued, financing is the remaining key hurdle in the path of the WESCO project. Because of the high cost and new technology, as well as government uncertainties, lenders will require federal loan guarantees for the initial plants to assure repayment of the debt. (auth)

Rudolph. R.F.H. Coal Gasification: A Key Process for Coal Conversion. pp 110-116 of In Proceedings of the Synthetic Hydrocarbons Conference. New York; American Inst., of Mining, Metallurgical, and Petroleum Engineers, Inc. (1974).

In the last two decades oil and natural gas have been the major raw materials and fuels, and have consequently determined the energy forms we are now accustomed to using, kinds of chemical products, the routes for their manufacture, and the cost structure. Coal has only been able to maintain its position in the power generation field. The current worldwide energy crisis has indicated that the relatively short period in which oil and natural gas supplies have been abundant has come to an end, and today it is a generally accepted fact that coal must again play an important and even greater role. The coal derivatives must be suited to the current market situation and the general standard of living, which in turn means that coal must be converted into energy forms and products that meet today's requirements. It should also be taken into account that, compared with oil and natural gas, coal conversion requires higher investments and generally has a lower efficiency. If coal is to be used on a broader scale as a source of various forms of energy and raw materials, the following questions arise: What technology is available? How much expenditure is required? What is the competitive situation with oil and natural gas? This paper attempts to answer these questions and to develop criteria regarding the technical and economic possibilities.

Salvador. L.A.; E.J. Vidt, J.D. Holmgren. Westinghouse Fluidized Bed Combined Cycle Process: Status of Technology and Environmental Considerations. (Westinghouse Research Labs., Pittsburgh). Jun 1976.

The conversion of coal to a clean, low Btu gas to fuel a combined-cycle power generation plant holds promise of being one of the most economic, efficient, and environmentally acceptable methods of utilizing coal resources to provide the nation's energy needs. Westinghouse Electric Corp. as leader of a government/industry team is developing this power generation system utilizing a multiple-fluidized bed process for devolatilization, desulfurization, and gasification of coal to produce low-Btu fuel for a combined-cycle power generation package. The team is implementing one of the first totally integrated coal conversion programs, from bench-scale to a complete coal to electric power energy conversion package. The program is presently in the design and development phase. Bench-scale development activities are being performed in conjunction with the operation of a 1200 lb/h process development unit (PDU) to evaluate process feasibility and operability. A conceptual design for a full-scale generating plant has been completed. The testing has been directed toward a number of technical and environmental considerations including the behavior of high-sulfur, caking coals, ash removal and disposal, sulfur removal and disposal, control of combustion product effluents, turbine protection, and product gas cleaning. Operation of the system to provide power in an efficient and environmentally acceptable way is feasible.

Schell, W.J. Separation of Coal Hydrogasification Gases by Permselective membrane. (Chemical Process Plants Co., El Monte, CA). Am. Chem. Soc., Div. Fuel Chem., Prepr.; 20. (1975).

A method is described that has the potential for improving the economics of coal gasification for the production of methane or methane and hydrogen. The advantages would be realized by separation of the hydrogen from the hydrogasifier effluent stream, thereby reducing the size of carbon monoxide shift reactors, lowering the volume of steam required in shift reactors, and reducing the size of waste heat recovery units. In a combined char, oil, and gas production scheme, the process would also provide sufficiently pure hydrogen gas for use in the hydrogenation of coal oil. The proposed separation method involves the use of permselective membranes that possess unusually high permeation rates and selectivity for hydrogen, thereby enabling hydrogen to be separated from coal-gas mixtures in an economical and efficient manner. In addition to a description of the applications of membrane perm-selectivity to coal gasification, membrane gas separation theory will be discussed. Examples of pertinent separations that could be performed, such as hydrogen-carbon monoxide, hydrogen-methane, helium-methane, carbon dioxane-methane and oxygen enrichment of air, are described. Finally, various membrane configurations that are currently employed in membrane gas separation modules, such as spiral wound and hollow fiber, are discussed in terms of application, operating variable, module size, and capacity.

Schora, F.C. Jr. "New" Coal Gasification Technology. pp 133-145 of In Proceedings of the Synthetic Hydrocarbons Conference. New York; American Inst. of Mining, Metallurgical, and Petroleum Engineers, Inc. (1974).

The early origin and modern developments of coal gasification are reviewed, and present economic feasibility is discussed. The chemistry of gasification is summarized. Six processes recognized as leading candidates for commercialization are briefly analyzed, and simplified flow diagrams are included. The processes are Lurgi and Koppers-Totzek (commercial), HYGAS and CO₂ Acceptor (pilot plants operating), and BI-GAS and Synthane (pilot plants under construction). Three methods developed by IGT to provide process hydrogen are explained; they are electrothermal, steam-oxygen, and steam-iron gasification. It is concluded that modern gasification processes, utilized to make clean pipeline-quality gas from coal would help resolve the energy crisis by making available energy from huge U.S. coal deposit, would have a beneficial effect on the GNP and the balance of trade, and might provide a hedge against inflation.

Seglin, L. Preliminary Evaluation of the SO₃-Coal Gasification Process. (Econergy Associates, New York (USA)). 25 Aug 1976. p. 83.

Process designs and estimated capital and operating costs, based on current dollars, were developed for an SO₃--Process Coal Gasification Plant, handling 10,000 TPD Illinois No. 6 Coal. This plant would produce 94 MM scfd pipeline gas and would export 330 to 430 Mw of electric power. From these derived data, pipeline gas prices needed to justify the required capital were defined. The effect of some of the uncertainties in the derived data on gas prices were developed, including: Price for coal, price for byproduct exported electric power, and capital requirements. Comparisons of the derived prices with those of alternate processes were noted only qualitatively, since it was not known whether or not these comparisons were on the same basis. Analysis process was mainly theoretical, since the process is conceptual and experimental data are lacking on gas compositions and yields and on the kinetics of the gasification reactions. Any further consideration of this process should include obtaining such relevant data. Prediction of the effect of changes from the theoretically derived performance on economics of the process is beyond the scope of this study.

Shmakova, E.K. Cost Benefits of Underground Gasification of Brown Coal With Thermal Preparation of the Coal Bed. Translated from Podzemn. Gazif. Uglei. p. 7.

When gasifying coal in accordance with the scheme for predominant gassing in the direction of the pillar and thermal preparation of the bed, the cost of 1,000 m³ of gas is reduced by 3.4 to 4.7 rubles (9 to 12 percent) as opposed to its actual cost at the Podmoskovnaya Station. A greater reduction occurs in the case of strictly maintained thermal preparation of the coal (in the blocks of boreholes with thermally prepared coal). In connection with the increase in heating value of the gas, the cost of one mega-calorie of the gas is reduced by 11 to 13 rubles, which amounts to 20 to 24 percent. This reduction in the gas cost increases the effectiveness of using it instead of coal by 25 to 30%.

Speich, P. Comparison of Brown Coal Conversion Processes. (Rhein Braunkohlenwerke, Cologne, Ger). (Dec 1976). (In German).

Conversion of brown coal into SNG, synthesis gas, methanol, and gasoline is discussed with respect to investment and production costs, raw materials utilization, conversion efficiency rates, and the market situation. Coal conversion processes are compared from the technical and economic standpoint. Competitiveness of coal in electric power generation with nuclear energy on one hand and with the oil and gas fossil energy carriers on the other is examined.

Stroud, H.T.F. Hydrogen of Methane: Future Processes for the Production of SNG. Energy Dig. (London); 6. (Aug 1977).

Possible future processes for the production of SNG from various feedstocks are discussed. The production of a gas which is largely methane appears to be the best way of husbanding resources. Among the processes considered are various methods of gasifying coal using nuclear heat.

Thomas, T.J. Effect of Energy Components on System Costs and Efficiency. (Battelle Columbus Labs., OH). Aug 1976.

It is assumed that the cost and efficiency of proposed energy delivery system components must be evaluated within the context of the system with which they are to be used, as the system inefficiencies can scale up the costs of the proposed components. Specifically, there exists a number of technologies by which the sulfur oxide emissions from the burning of coal can be minimized. These technologies are attractive on paper, but their use may greatly affect total system cost and efficiency. A methodology is presented by which total system cost and efficiency may be easily calculated. Individual component contributions to total system cost and inefficiency are also developed by this methodology. This methodology is applied to six example energy delivery systems based upon the delivery of 1 MWe of electricity (from coal) to a midwest area. Each system has some form of sulfur removal, and each represents the most optimal system of a set of systems using nearly the same components in various combinations. The results show clearly the effect of major system components, including sulfur removal techniques, on total system cost and efficiency. Potential areas for improving system efficiency at little or no cost are delineated.

Todd, R.W. WESCO Project: The Decision-Making Processes. pp 147-156 of In Proceedings of the Synthetic Hydrocarbons Conference. New York; American Inst. of Mining, Metallurgical, and Petroleum Engineers, Inc. (1974).

Pacific Lighting Corp. of Los Angeles and Texas Eastern Transmission Corp. of Houston propose to develop a \$447 million coal gasification project on Navajo Tribal lands in northwestern New Mexico. Western Gasification Co. (WESCO), a joint venture of these two firms, will build and operate the gasification processing plant and related facilities. Utah International, Inc. will supply the necessary coal and water. The project is designed to produce 250 million cubic feet per day of substitute natural gas. This new supply will supplement dwindling natural gas reserves of Transwestern Pipeline Co., a Texas Eastern subsidiary. Based on promising early indications, Pacific Lighting and Texas Eastern agreed in September 1971 to undertake a joint feasibility study. The research program was launched by a small management team capable of expanding as requirements grow. The WESCO organization was officially established in early 1973 as an outgrowth of this original

With the completion of various preparatory activities, an application for project authorization was filed with the Federal Power Commission on February 7, 1973. Approvals and special permits also are required from many other federal and state agencies. In addition, a property lease agreement must be negotiated with the Navajo Nation for the coal gasification plant site and related facilities. Receipt of project authorization will be followed by detailed plant design, engineering, procurement and construction. These activities will consume approximately 32 months. The present target date for plant startup is late 1977.

Weinstein, H. Gas Core Reactors for Coal Gasification. (Illinois Inst. of Tech., Chicago). Sep 1976.

The concept of using a gas core reactor to produce hydrogen directly from coal and water is presented. It is shown that the chemical equilibrium of the process is strongly in favor of the production of H_2 and CO in the reactor cavity, indicating a 98% conversion of water and coal at only 1500°K. At lower temperatures in the moderator-reflector cooling channels the equilibrium strongly favors the conversion of CO and additional H_2O to CO_2 and H_2 . Furthermore, it is shown the H_2 obtained per pound of carbon has 23% greater heating value than the carbon so that some nuclear energy is also fixed. Finally, a gas core reactor plant floating in the ocean is conceptualized which produces H_2 , fresh water and sea salts from coal.

Wheelock, T.D., A.H. Pulsifer. Electrofluid Gasification of Coal With Nuclear Energy. (Iowa State Univ. of Science and Technology, Ames (USA). Engineering Research Inst.) (Jan 1978).

The gasification of coal by reaction with steam requires the addition of large amounts of energy. This energy can be supplied by a high-temperature nuclear reactor which is coupled to a fluidized bed gasifier either thermally or electrically via an electrofluid gasifier. A comparison of the economics of supplying energy by these two alternatives demonstrates that electrofluid gasification in combination with a high-temperature nuclear reactor may in some circumstances be economically attractive. In addition, a review of recent experiments in small-scale electrofluid gasifiers indicates that this method of gasification is technically feasible.

Wiggins, D.S.; J.J. Williams. Engineering Evaluation of Process Heat Applications for Very High Temperature Nuclear Reactors. (United Engineers and Constructors, Inc., Philadelphia, Pa. (USA)). 9 Mar 1976. p. 145.

Coal gasification and liquefaction processes and costs are reviewed. Nuclear-heated processes based on 3000-Mwt reactors are compared to the principal fossil-heated coal conversion processes of similar size. The published processes are technically feasible, and costs are consistent with United Engineers' experience.

If a 15% fixed charge rate and \$0.50/106 Btu coal can be obtained, and costs published by proponents of these processes are valid: (1) coal can be converted to pipeline gas at a cost competitive with unregulated natural gas; (2) coal can be converted to heavy naphtha and heavy oils at a cost competitive with the present cost of imported oil; (3) synthesis gas ($\text{CO} + \text{H}_2$) obtained from coal can be converted to methanol significantly cheaper than the current market price; and (4) synthesis gas is also attractive for the reduction of iron ore. The costs of coal conversion are very sensitive to the fixed charge rate and the coal costs, and may not be competitive for higher values. At low coal costs, nuclear-heated processes are more expensive than fossil-heated. At high coal costs, nuclear processes become less expensive than coal. The applicability of nuclear-heated coal conversion is limited because the size of the plant is too great for many mine-mouth operations. Much smaller fossil-heated plants can be built without a significant increase in product cost.

Wooten, J.T. WESCO or ANY-CO: There Must Be a Way. pp 109-123 of In Proceedings of a Symposium On Coal Dilemma: How and Where To Use It. Denver; Cameron Engineers, Inc. (1976).

The history of the WESCO project to supply substitute natural gas for use directly and to supplement natural gas supplies is given briefly. The Lurgi process was chosen in view of its commercialization elsewhere. The design was drawn up. The Federal Power Commission decided it did not have jurisdiction over the gasification plant but would have jurisdiction of the transport and sale price of the gas produced. But Wesco could not be sure of capital recovery if there were delays in construction and wanted a loan guarantee by the Federal Government. A bill proposing this passed the Senate but failed in the House. Following the FPC's rejection of jurisdiction of the gasification plant, the US Department of the Interior accepted the role of lead agency in preparing an Environmental Impact Statement. This took 32 months to complete, and a construction permit was finally issued in September, 1974. But there is evidence that the Federal EPA may change its requirements for gasification plants. Also after 3 years of negotiation the Navajo Tribal council has not yet approved a plant-site loan agreement, but may be close to doing so. In the meantime, as a result of the delay, coal supply contracts have had to be renegotiated twice. If a loan guarantee is approved ERDA will require 3 months to evaluate the project and 15 months to implement the program. (LTN)

COAL GASIFICATION-ENVIRONMENTAL IMPACTS

Environmental Assessment of the HYGAS Process.

Monthly Progress Report, April 1--April 30, 1977. (Institute of Gas Technology, Chicago, Ill. (USA)). Aug 1977. p. 25.

Hygas tests were carried out with Montana subbituminous nonagglomerating coal and with Illinois bituminous coal. Sulfur-by-species determinations were completed on reactor solids for some tests, and concentrations of selected pollutants in Hygas aqueous streams are also reported for one test. Final data from one test indicated that Be, V, Mn, Zn, Li, Cr, and Pb essentially remained in the ash, and from 50 to 90 percent of the Fe, Ba, As, B, F, Tl, Ni, Cu, and Mo also remained in the ash. The most reactive elements were Cl, Se, Cd, and Hg with less than 50 percent recovery in the ash. An ash balance also implied that Fe, As, Ge, Tl, Ni, Cu, Cd, and Mo were primarily released in the steam-oxygen zone; Ba, B, Cl, and Hg were primarily released in the first and second stages of gasification. There is some evidence for the accumulation (by an unknown mechanism) of Fe, Tl, Ni, Cu, Cd, Pb, Mo, and Cr in the upper, cooler sections of the gasifier. A comparison of trace element analyses with earlier tests with lignite shows that they agree for Li and Mn but that substantial differences are evident for the remaining comparable trace elements. The production of selected pollutants in Hygas water effluents is presented on a normalized basis. Rudimentary S material balances around the pretreater and around the gasifier are presented as an aid in ascertaining the ultimate fate of S during gasification.

Coal Technology Program Progress Report, July 1977.

(Oak Ridge National Lab. Tenn. (USA)). Aug 1977. p. 54.

In hydrocarbonization research cold model tests are being conducted to determine conditions that will enhance mixing in the recirculating fluidized bed reactor and make it more suitable for the hydrocarbonization of caking coals. In the pressurized carbonization of Consol Synthetic Fuel residue, five runs were completed that show a desirably low rate of coking of the recycle solvent that is used to slurry the residue. Fracture toughness studies of thick steel plates are continuing. The effects of important welding variables such as current, travel speed, and torch oscillation on the depth of penetration and dilution of type 320 Cb stainless steel cladding deposits have been evaluated for deposits made by the submerged-arc process. A 1000 hr exposure of heat exchanger tubes to the fluidized bed combustion conditions of a Fluidyne bed was started. Inconel 600 tubing failed by catastrophic sulfidation after a few days. In the gas-fired potassium boiler project, the

major portion of the potassium piping installation was completed and connections of the electrical and instrument wiring between the control room and the system are being made. In the coal-fired alkali metal power system design study, several variations of the cycle arrangement for the selected atmospheric pressure fluidized bed combustor were completed, a preferred concept for the furnace developed, the coal feed and ash handling system was designed, and work continued on the alkali metal condenser-steam generator.

. Coal Technology Program Progress Report for August 1977. (Oak Ridge National Lab., Tenn. (USA)). Oct 1977. p. 65.

The projects reported this month include those for coal conversion process development, materials engineering, alkali metal vapor topping cycles, a coal equipment test facility, a fluidized bed combustor technology test unit, engineering and support studies, process and program assistance, and environmental assessment studies. In hydrocarbonization research, material balance results from Run HC-21 confirm earlier tests with Wyodak coal, showing an oil yield of 21% based on MAF coal. In the coal-solvent-hydrogen mixing work, experiments were completed with the Kenics mixer reactor and with the packed-bed reactor. The fracture toughness characterization of 25.4-cm-thick ASTM A543 Class 1 plate is in progress. In the gas-fired potassium boiler project, we completed and leak-tested all of the potassium piping for the system and made preparations for loading the drain tank with potassium. The design work on the fluidized-bed, alkali-metal-vapor cycle system has been completed. In the engineering studies and evaluations project, work was continued on process modeling, the preparation of a Synthetic Fuels Research Digest, a survey of industrial coal conversion equipment capabilities, and studies of flash hydro-pyrolysis, hot gas purification processes, processes for heat recovery, and hydrogen production by the steam/molten iron process. In the process and program analysis studies, studies were continued on low-Btu gasification, direct combustion, advanced power conversion systems, liquefaction, high-Btu gasification, in situ gasification, and coal beneficiation. The Environmental Monitoring Handbook is being used extensively by contractors and their environmental subcontractors in designing monitoring programs for the nation's first fossil demonstration plants.

. Coal Technology Program. Progress Report, September 1977. (Oak Ridge National Lab., Tenn. (USA)). Oct 1977. p. 56.

A successful hydrocarbonization experiment at 300 psi of hydrogen and approximately 1050°F was completed with Illinois No. 6 coal that had been chemically pretreated with aqueous CaO and NaOH. In pressurized carbonization, one successful experiment at approximately 1100°F and 415 psi of methane was completed with vacuum distillation residue from the H-Coal process. In the thick section pressure vessel work, procedures are being developed with the DATA

TRAK heat treating facility to allow preparation of relatively large heat treated samples of 2 1/4 Cr-1 Mo steel. In the Gas-Fired Potassium Boiler Project, the potassium system installation was completed, the fill and drain tank was filled with potassium, and the checkout of the instruments and controls was nearly completed. The Coal-Fired Alkali Metal Power System Design Study was completed and a draft report describing the design was issued. Cesium was selected as the working fluid for the topping cycle. For the reference design, the furnace operated at atmospheric pressure and the cycle conditions for the power conversion systems were 1500°F (1089K) to 900°F (756 K) for the topping cycle and 2400 psi (16.5 MPa)/1000°F (811 K)/1000°F (811 K) to 1 1/2 in. Hg (5079 Pa) for the steam system. ORNL was requested by DOE to develop a program for testing coal feeders currently under development. Work was continued on process modeling, the preparation of a Synthetic Fuels Research Digest, a survey of industrial coal conversion equipment capabilities, and studies of flash hydrophrolysis, hot gas purification processes for heat recovery, and hydrogen production by the steam/molten iron process. Process and program analysis studies were continued on low-Btu gasification, direct combustion, advanced power conversion systems, liquifaction, high-Btu gasification, in situ gasification, and coal beneficiation.

. Balanced Program Plan. Volume 4, Coal Conversion.
(Energy Research and Development Administration, Washington, D.C. (USA). Div. of Biomedical and Environmental Research). May 1976. p. 316.

This document contains a description of the biomedical and environmental research necessary to ensure the timely attainment of coal conversion technologies amenable to man and his environment. The document is divided into three sections. The first deals with the types of processes currently being considered for development; the data currently available on composition of product, process and product streams, and their potential effects; and problems that might arise from transportation and use of products. Section II is concerned with a description of the necessary research in each of the King-Muir categories, while the third section presents the research strategies necessary to assess the potential problems at the conversion plant (site specific) and those problems that might effect the general public and environment as a result of the operation of large-scale coal conversion plants.

. Advanced Fossil Fuel and the Environment: An Executive Report. (Environmental Protection Agency, Washington, D.C. (USA)). Jun 1977. p. 27.

The environmental control technologies being developed in conjunction with advanced fossil fuel conversion processes are briefly reviewed. These programs include chemical coal cleaning, synthetic fuels, chemically active fluid bed, oil shale, and liquid fuels cleaning. Comparative economics of sulfur control and a reading list are included. (LW)

. Bibliography of the Environmental Protection Agency's
Office of Research and Development Energy-Related Publications.
(Environmental Protection Agency, Denver, Colo. (USA). Office of
Energy Activities.). Mar 1977. p. 26.

This bibliography consists of a list of publications dealing with energy resource development and its accompanying environmental effects. The publications listed are taken from Office of Research and Development (ORD) publications summaries and from lists provided by the Industrial Environmental Research Laboratory's Resource Extraction and Handling Division.

Ball, D.A. Low Energy Gas Retrofit to Industry. (Battele Columbus Labs., Columbus, OH) Jun 1976.

Low- or intermediate-energy gas from coal (with a heating value of 150 to 400 Btu/scf) is an alternate fuel for industries faced with reduced availability of natural gas and an uncertain fuel oil supply. Such a gas can be produced and cleaned of such contaminants as particulates, sulfur, and nitrogen compounds using commercially available technology. A description is given of the conversion of two hypothetical industrial plants (a petroleum refinery, and a secondary steel mill) to onsite production of low- and intermediate-energy gas from coal as a source or process energy. Specific gasifier and gas cleanup equipment requirements are discussed for the hypothetical plants, considering such factors as peak plant load, assumed coal source, and process and piping requirements. The possibility of utilizing existing plant piping and gas burners is discussed. General material and energy flows are presented. The potential environmental impact of conversion to gas from coal is also discussed in terms of emissions from both the gasification process and the combustion process.

Beychok, M.R. Process and Environmental Technology for Producing SNG and Liquid Fuels. Washington, DC; Environmental Protection Agency (May 1975). p. 143.

This study conducted by the U.S. Environmental Protection Agency covers the production of SNG from LPG, naphtha, coal, or crude oil; LNG, including liquefaction at the source, regasification at market and importation from overseas; liquid methanol fuel; natural gas pipelines, including gas transmission pipeline costs, a comparison of 1972 pipeline capacity with the output at hypothetical SNG, LNG, and methanol plants, and environmental factors such as land disturbance along right-of-way, production of liquid fuels from oil shale, and coal liquefaction. The environmental emissions and effluents from each technology are identified and quantified, with specific examples from actual designs. A brief description of the process technology involved is presented in each case. The data provided cover air emissions, water disposition, effluent treatment, thermal balances, noise factors, solid wastes, and some socioeconomic factors.

Boegly, W.J. Jr; H.S. Arora, E.C. Davis, R.G.S. Roa, H.W. Wilson Jr.
Experimental Study of Leachate From Stored Solids. Quarterly
Report, June 1, 1977--January 1, 1978. (Oak Ridge National Lab.,
Tenn. (USA)). Jan 1978. p. 38.

This quarterly report is the first one. The basic aim of the program is to determine the environmental acceptability of land-filling solid residues from coal gasification facilities, and also to evaluate potential environmental degradation caused by leachate produced by rainfall on coal storage piles. This report outlines the program plan, discusses waste types to be studied, provided details of the solid-waste leaching studies, describes existing hydrologic models that can be used for predicting contaminant movement, describes results of a literature review of coal pile runoff, and outlines a laboratory and field program to evaluate coal pile leachate.

Bolton, N.E. Defining an Adequate Industrial Hygiene Program for Coal Conversion Technology is a Complex Problem. (Oak Ridge National Lab., Tenn. (USA)). 1977. p. 17.

The information was prepared for oral presentation only, and there is no test. Copies of visual aids constitute the entire manuscript.

Bonham, J.W.; W.T. Atkins. Process Comparison Effluent Treatment Ammonia Separation. Final Report. (Braun) C.F.) and Co., Alhambra, Calif. (USA)). Jun 1975. p. 11.

Commercial concept designs are being developed for candidate coal gasification processes. A part of this effort is to determine if there is an economic justification for recovering ammonia from process waste waters. This report presents the results of that study. Based on the waste water feed and the current product ammonia price used in this study, ammonia recovery is economically attractive. Of the two ammonia recovery processes studied, the USS Engineer process has both lower capital and operating costs and is recommended for use in future commercial concept designs.

Cavanaugh, E.C.; W.C. Thomas. Environmental Assessment of Low/Medium Btu Gasification. Annual Report, March 1976--October 1977. (Radian Corp., Austin, TX (USA)). Dec 1977. p. 35.

The report summarizes completed and on-going work performed by Radian Corporation for the EPA in the area of environmental assessment of low- and medium-Btu gasification of coal and its utilization. Main areas discussed are the current process technology background, environmental data acquisition, and control technology assessment. Information presented gives a general understanding of what has been accomplished and what can be anticipated.

Ehrenfeld, J.; B. Gehron, M. Goldberg, J. Gushue, B. Ross. Environmental Research Needs for Coal Conversion and Combustion Technologies, Final Report. (Energy Resources Co., Inc., Cambridge, Mass. (USA)). Dec 1976. p. 307.

The results of an examination of the Federal environmental research program concerned with coal-using technology are presented. The general objective of the work is to assist the Council on Environmental Quality in carrying out its assessment of the adequacy of attention to environmental protection in Federal Research, Development and Demonstration (R and D) programs. It is important to note that the basis for this study, particularly in setting priorities, is tied to decision-making, regulatory, and planning processes associated with Federal coal-Technology development and utilization programs, not to the environmental impact, per se, of the ultimate introduction of that technology in the economy. This aim stresses current and near-term understanding of sources, effects and consequences, rather than ultimate fundamental knowledge of all of the causal mechanisms leading to the generation, transport, control and effects of pollutants.

Epler, J.L.; F.W. Larimer, T.K. Roa, C.E. Nix, T. Ho. Energy-Related Pollutants in the Environment: The Use of Short-Term Tests for Nutagenicity in the Isolation and Identification of Biohazards. (Oak Ridge National Lab., Tenn. (USA)). 1978. p. 31.

In an effort to gather information on the potential genetic hazards of existing or proposed energy generating or conversion systems, we have begun a correlated analytical and genetic analysis of a number of technologies. The work is divided into two phases: one dealing with known compounds expected to occur in the environment through energy production, conversion, or use; and the other dealing with actual samples from existing or experimental processes. To approach the problems of dealing with and the testing of large numbers of compounds, we set up a form of the tier system. Operating units utilizing Salmonella, E. Coli, yeast, human leukocytes, mammalian cells, and Drosophila have been initiated. Various liquid-liquid extraction methods and column chromatographic separations have been applied to crude products and effluents from oil shale, coal liquefaction, and coal gasification processes. Mutagenicity of the various fractions is assayed using reversion of histidine-requiring auxotrophs of Salmonella typhimurium and comparative studies are carried out with the other genetic systems. In order to incorporate metabolic activation of these fractions and compounds, rat liver homogenates are used in the various assays. Results implicate chemicals occurring in the basic and the neutral fractions as potential genetic hazards. Chemical constituents of these fractions (identified or predicted) were tested individually for their mutagenic activity and correlated with the genetic monitoring.

Fleming, D.K. Technology and Environmental Impact of Coal Gasification Processes. (Institute of Gas Technology, Chicago, Ill. (USA)). 1975. p. 23.

Exponentially increasing requirements for new energy in the U.S. can be anticipated. Our energy reserves, however, are limited. Even with maximum expansion of nuclear power generation and other energy from non-conventional sources, we must rely heavily upon our coal reserves through the end of this century. Gasification of coal appears to be a logical and environmentally satisfactory use of that resource. Several technologies for coal gasification either exist or are emerging. In general, coal gasification is divided into three areas: (1) low-Btu gas for direct combustion, (2) intermediate-Btu gas produced as a synthesis gas for coal-chemical manufacture, and (3) high-Btu gas production. In general, the purification requirements for the second and third classes of coal gasification are similar and should result in minimal degradation to the environment, perhaps an order of magnitude less than production of the same quantity of energy in the form of electricity in accordance with present standards. Purification of low-Btu gas, however, is required for environmental considerations only. These environmental constraints and their influence on process economics suggest that the short-term expected emissions will be similar to the alternative overall system of burning the coal directly with stack-gas desulfurization.

Floyd, G.R. Potentials of Correlation Absorption Spectroscopy for Real-Time Monitoring of PNA Emissions. (Barringer Research Ltd., Toronto). Dec 1977.

The production of PNAs during coal gasification presents many problems, one of which is the monitoring and measurement of the levels of these carcinogens, both in the environment of the plant and in the surrounding area. The Gas Filter Correlation Spectrometer, called GASPEC, is well suited to monitor PNA levels, both in the gasification plant and its environs. The GASPEC is a nondispersive correlation instrument which operates in the infrared (IR) spectrum. In effect, it compares the incoming IR spectrum of the target gas with that of a sample of the target species contained within the instrument and generates an electrical output proportional to the burden of target vapor observed. Infrared energy from a source such as the earth passes through the atmosphere, acquiring spectral information about its various constituents. The radiation incident in the instrument is gathered and band limited by the optics. The scene energy is split optically and is caused to pass through two gas cells--one containing the gas of interest, the other, the reference cell, being evacuated. The channel with the gas cell is unresponsive to spectral information about the target gas, while the reference arm is very sensitive to any spectral content. The outputs of each arm are differenced, and after

further electronic processing produce a final output, AV, proportional to the target gas burden. Calculations for both ambient and remote sensing modes suggest that GASPEC would be capable of detecting very small concentrations of PNAs and thus would be a very effective real-time monitor of PNA levels in coal emission plants. (JRD)

Glazer, F.; A. Hershaft, R. Shaw. Emissions From Processes Producing Clean Fuels. Final Report. (Booz, Allen and Hamilton, Inc., Bethesda, Md. (USA)). Mar 1974. p. 447.

Processes for converting coal, oil and shale to clean fuels were studied. Most of the processes considered have not yet been developed to commercialization. Based on preliminary data and engineering estimates developed, it can be concluded that: (1) unit processes apparently exist to provide adequate control of most waste streams from clean-fuel plants, although some pollutants remain difficult to treat; (2) the pollutant emissions from clean-fuel processes will, in general, be relatively low when compared to emissions from alternative uses of the raw fuel; (3) the total costs of pollutant control (1973) basis for achieving low levels of plant emissions, in high-Btu coal gasification processes, range from 15 to 30 cents per million Btu and can be expected to increase in proportion to the severity of the emission controls required; (4) low-Btu gasification followed by desulfurization may be considered as a pollution control system because it permits the combustion of coal with decreased emissions. In that case the overall cost of pollution control is about \$0.65/10 to the sixth power Btu of gas produced. (GRA)

Goldberg, A.J. ERDA's Impact Assessment of Gas Production. pp 183-196 of In Proceedings of a Symposium On Coal Dilemma: How and Where to Use It. Denver; Cameron Engineers, Inc. (1976).

The goal of the programmatic Environmental Impact Statement for the Office of Fossil Energy is not specificity as one would find in a site-specific impact statement, but rather a search and analysis of the larger effects which, despite the uncertainty of the data and the variability in all parameters, would suggest directions either for new technology initiatives on the part of the Office of Fossil Energy or initiatives in environmental health and safety research and development either in the Fossil Energy Office or elsewhere in ERDA. A corollary of the activity is a systematic identification of environmental health and safety information that might be missing and for which further investigation would be required. The objectives then are: first of all, to describe the environmental effects of the proposed activity, and in this case, the activity covers the full spectrum of all the fossil energy's research; secondly, to look at the alternatives outside the Office of Fossil Energy and within the program; thirdly, to suggest mitigating

actions to reduce the potential impacts; and, finally, to provide a body of information so that the federal government, in general, and ERDA, in particular, can have that information as a basis for decision-making about its programs and about its directions. Based on the data we are going to present, we would not propose new technology goals at this time. We would, however, see a serious deficiency in our understanding of some potential impacts, and would recommend strongly that the appropriate R and D efforts be undertaken to clarify those (trace element disposition, effluent compositions, transport and transformation of potentially hazardous substances, dose-response relations, health effects).

Goldstein, D.J.; D. Yung. Water Conservation and Pollution Control in Coal Conversion Processes. Final Report June 1975--December 1976. (Water Purification Associates, Cambridge, Mass. (USA)). Jun 1977. p. 486.

The report gives results of a study to determine water consumption and environmental impacts of coal conversion processes in Western states. Part 1 gives brief descriptions and process water requirements for nine conversion processes. Detailed designs and analyses are given for the Hygas, Synthane, and Solvent Refined Coal (SRC) processes, and for Lurgi combined-cycle power generation. At three proposed sites (in North Dakota, New Mexico, and Wyoming), complete water requirements and effluents, including all mining and related off-site uses, are given for the power, Hygas, and SRC plants. The Synthane process is analyzed only at the Wyoming site. Part 2 gives analyses of influent and effluent waters, with examples for study. For the three selected plants at the North Dakota site, source water of good quality is assumed to be cheap and available. For three plants in New Mexico, source water will be available but is brackish. All the plants at the Wyoming site receive sewage from a satellite town; additional fresh water is available but is assumed to be expensive. For each process at each site (10 cases) an integrated water treatment plant block flow diagram is given with approximate costs and energy requirements.

Hebden, D. High Pressure Gasification Under Slagging Conditions. (British Gas Corp., London). 1976.

Gasification of coal primarily involves the reaction of steam with carbon to produce carbon monoxide and hydrogen, with secondary reactions producing carbon dioxide and methane. The primary reaction is endothermic and requires heat to support it at an appropriate kinetic level. While the secondary reactions are exothermic, they can only make a small contribution to the heat requirement of the primary gasification reactions. The bulk of this heat requirement can be provided in a number of ways, for example, directly as the heat by combustion of some of the fuel in oxygen. The gasification of coal also involves the separation and removal of ash from the reaction system, an operation with which the conduct of gasification must be compatible. The ash can be separated

and removed in a number of ways, as a dry unfused granular material, as splintered granules or as a liquid slag. This paper deals with fixed bed gasification in steam and oxygen under pressure and in particular with a development of the Lurgi gasifier which, by allowing it to be operated under slagging conditions, greatly extends its capability to gasify coals of a wider range at higher efficiencies and at greatly increased outputs. The development is a natural evolution of the traditional Lurgi gasifier which it complements.

Ho, C.H.; B.R. Clark, M.R. Guerin. Direct Analysis of Organic Compounds in Aqueous By-Products From Fossil Fuel Conversion Processes: Oil Shale Retorting, Synthane Coal Gasification, and COED Coal Liquefaction. (Oak Ridge National Lab., TN). (1976).

Whole water samples are injected directly into a gas chromatograph equipped with a packed Tenax-GC column. Polar compounds are separated with good resolution under the temperature programming conditions employed. The by-product water from oil shale retorting contains carboxylic acids in the homologous series ranging from acetic to decanoic acid. Various amides, cresols and phenol are present in trace amounts. Coal conversion by-product waters also contain carboxylic acids, but in trace amounts (except acetic). Major components among the dissolved organics in coal conversion samples are phenol, o-creso, m-cresol and p-cresol. Present at lower levels are several other alkyl substituted phenols and naphthols.

Hundemann, A.S. Pollution and Environmental Aspects of Fuel Conversion (a Bibliography with abstracts). Report for 1964--Mar 77. (National Technical Information Service, Springfield, Va. (USA)). Apr 1977. p. 172.

Abstracts dealing with environmental impacts related to fossil fuel conversion processed (primarily coal gasification) are presented. A few citations concerning environmental considerations pertaining to future energy growth are included. (This updated bibliography contains 167 abstracts, 80 of which are new entries to the previous edition.)

Kalfadelis, C.D.; E.M. Magee, G.E. Milliman, T.D. Searl. Evaluation of Pollution Control in Fossil Fuel Conversion Processes. Analytical Test Plan. Final Task Report. (Exxon Research and Engineering Co., Linden, N.J. (USA)). Oct 1975. p. 186.

The report gives results of a preliminary definition of those streams which require analysis to permit an assessment of the pollution potential of the processes in the light of current environmental standards, using a coal gasification process (Lurgi) and a coal liquefaction process (COED) as a basis. It defines methods for sampling indicated streams and analytical procedures

which are required to obtain the data. These summaries may be readily modified or adapted to other processes, and expanded to include additional pollution constituents or improvements in analytical procedures. The report also contains the industrial set up of the processes for gasification and liquefaction of coal. (GRA)

Klein, J.; H. Juentgen. Water Circuit and Waste Water Treatment for Gasification Processes. (Bergbau-Forschung G.m.b.H., Essen (Germany, F.R.)). pp 500-514 of In Compendium 76/77. Klamann, D.; F. Asinger, H. Boigk, H.H. Oeler, W. Peters. (eds.). (1976). (In German)

The fact that new importance is attached to coal gasification for production of heating gas and SNG led to considerable endeavors being made in all industrialized countries in order to develop suitable processes or to advance the classic processes for gasification. In this respect the availability of treated water for the gasification process and, furthermore, waste water treatment are an essential criterion, especially for the question of site for the planned gasification plants. Due to the large quantities of water required (400 to 500 t/h for a plant capacity of approximately 2 million $m^3_{sub(n)}/a$ SNG) a water recycling system is advisable which, however, imposes considerable requirements on waste water treatment. A representative series of waste water samples from industrial coal gasification plants working at low temperatures under pressure was analysed in detail in order to determine processes for purification. With the processes available at present for waste water treatment the high amount of impurities contained in the process waste waters make the recycling process difficult. Practical research on adsorptive purification by means of activated carbon have shown that a good purification performance can be reached, i.e. loads up to 150 to 200 kg of C/ m^3 of activated carbon. These results may show ways to waste water treatment by a circuit system for gasification plants. After having discussed possible treatment phases, a combination of processes is proposed enabling to deal by a circuit system with the majority of waste water produced in gasification plants. This proposal is subsequently compared to a very costly kind of process in connection with the American El Paso project for pressurized gasification by the Lurgi process.

Little, Arthur D.; Inc. Outlook for Research and Development in the Underground Gasification of Coal. Cambridge, Mass. (USA)). Nov 1975. p. 44.

This report deals with the potential of in situ coal gasification technology in comparison with conventional coal extraction and utilization to produce pipeline gas or electricity. It also discusses the nature of the research and development program that appears warranted to bring the technology to the state of commercial acceptance and identifies significant technical problem areas.

Massey, M.J. Approach to Residuals Management in Coal Conversion Processing. (Carnegie-Mellon Univ., Pittsburgh). 1976.

The basic characteristics of coal conversion are briefly reviewed; it can be viewed as the hydrogenation of coal. Major and alternative strategies in coal gasification and liquefaction are examined. Characteristics of coal gasification plant effluent production are studied, with data given for a Synthane gasifier, and for Hygas and CO₂-Acceptor gasification of lignite.

McNeese, L.E. Fossil Energy Program. Progress Report for February 1978. (Oak Ridge National Lab., Tenn. (USA)). May 1978. p. 54.

In support of in situ gasification, block pyrolysis experiment BP2-44 was conducted in which a bituminous coal block was heated to 650°C in three steps using a H₂ reactor purge gas. Swelling of the block and plastic behavior during pyrolysis were substantially reduced at the higher heating rate of this experiment (5 C°/min) compared with previous experiments at a heating rate of 3 C°/min. The first CoCrAlY specimens have been plasma sprayed in our coatings inspection program. In the welding and cladding program, the first samples of 2 1/4 Cr-1 Mo steel with a clad overlay of type 320 Cb were prepared by submerged arc welding with an alloy-fortified flux. No fissuring was detected either visually or by dye penetrant inspection. Experimental work in the fireside corrosion tests to expose various heat exchanger tubes at the Fluidyne atmospheric fluidized bed combustor continues. Scale on types 304, 310, and 216 stainless steels and Alloy 800 exposed for 1000 and 1500 hrs is composed primarily of Ca compounds and coal ash with minor amounts of iron, nickel, and chrome oxides. In the gas-fired potassium boiler experiment, 4.5 hrs of stable boiling operation was obtained at power levels up to about 3×10^6 Btu/hr. A potassium leak occurred at a 2-in. tee where liquid potassium streams from the condenser and the gas separator mix. Work is in progress for repairing the system. In the work on environmental controls for low-Btu gasification, preliminary estimates of the raw, low-Btu product gas and the aqueous wastes likely to be generated in the gasification of coal by four representative gasifiers have been developed. Work continued on an evaluation of an in situ coal gasification facility for producing methanol which would then be converted to gasoline via the Mobil-M process.

McLaughlin, S.B.; D.S. Shriner. Plant-Pollutant Interactions and The Oak Ridge Approach to Air-Pollutant Impact Analysis. (Oak Ridge National Lab., Tenn. (USA)). 1976. p. 23.

The processes by which pollutants move from the atmosphere to sites of action within plant cells are influenced by a wide variety of physical, chemical and biological factors. Of major importance among these are the physical and chemical form of the pollutants, the kinetics of the pollutant exposure regime, the solubility of

pollutants in cell systems, and their biological reactivity. The impact of a given dose on plant response is mediated by the above factors as well as many plant-related variables. Present needs in air pollution research relative to interactions of these factors are discussed with special emphasis on chronic impacts of potential regional scale significance. Current air pollution research at Oak Ridge includes both process level studies dealing with the impact of pollutants on plant physiology and growth, and regional scale studies designed to consider pollutant transport and effects on forest systems. In process-level studies major emphasis is being placed on the effects of individual and combined exposures with SO₂, ozone, and acid precipitation. In addition, the effects of a variety of organic effluents of potential importance in developing coal conversion technologies are being studied. Studies related to regional environmental problems are being initiated to consider air pollution effects of forest systems over large temporal and spatial scales. These studies will rely heavily on air transport models to describe pollutant distribution and forest growth models to describe probable long-term impacts of pollutants on forest growth and composition.

Neufeld, R.D.; T. Valiknac. Preliminary Evaluation of the Biological Oxidation of Thiocyanates. Progress Report, November 30, 1977--February 28, 1978. (Pittsburgh Univ., Pa. (USA). Dept. of Civil Engineering). Mar 1978. p. 24.

Acclimated biological cultures were developed from activated sludge taken from coke plant biological waste treatment facilities. These cultures are capable of degrading potassium thiocyanate from an original concentration of 2000 mg/l SCN to less than 1 mg/l in an aeration period of 9 hours. pH inhibition appears to be significant at values greater than 7.6. Substrate inhibition occurs at concentrations of thiocyanate greater than 500 mg/l. Air stripping of thiocyanate does not appear to occur at neutral pH value. Preliminary assessments indicate that aerobic biological organisms may play a major role in the removal of aqueous thiocyanate as found in the waste waters from the gasification of certain coals.

Peduzzi, M.P.; D.G. Nichols. Environmental Analysis Technique for Coal Conversion Process Studies. (West Virginia Univ., Morgantown, WV). pp 1-6 of In Energy and the Environment. Theodore, L. (ed.). Dayton, OH; American Institute of Chemical Engineers (1976).

An environmental analysis and impact evaluation technique has been developed for application to alternative processes for converting coal to other forms of energy by determining which conversion process would have the least impact on the environment. The method involves the determination of individual index values for each process step representing a sequence of subcategories of the environmental classes considered. The matrix of index values are then used to generate an overall environmental impact index for each alternative process system for each proposed location. The method is demonstrated on three different processes for converting

coal energy to electrical power, namely coal combustion in a pulverized fuel-boiler system with stack gas clean-up, coal gasification to low-Btu gas followed by combined-cycle power generation, and the solvent refining of coal followed by a conventional combustion system. These processes have been evaluated at various sites to deduce the sensitivity of the results to geographic differences.

Richmond, C.R. Testimony Presented to the U.S. Environmental Protection Agency's Public Hearing on Environment and Conservation in Nonnuclear Energy Research and Development, March 31, 1978, Washington, D.C. (Oak Ridge National Lab., Tenn. (USA)). May 1978. p. 31.

The author cites Public Law 92-577, The Nonnuclear Energy Research and Development Act of 1974, as mandating this Public Hearing as a forum to review the adequacy of emphasis on energy conservation and environmental implications of the Federal energy R, D and D program. President Carter directed ERDA (now DOE) and EPA in May 1977 to jointly develop procedures for establishing environmental protection standards for all new energy technologies and asked that the procedures be agreed upon within one year. The author first discusses general issues before he specifically addresses the subject of oil shale and synthetic fuels from coal. Specific issues are availability of these fuel technologies, impacts of implementation.

Rolan, R.G. Task Summary Report V: The Design and Implementation of an Environmental Monitoring Program for ERDA Fossil Fuel (USA)). Apr 1977. p. 86.

These guidelines outline a procedure for the detailed design and specification of environmental monitoring projects relating to all coal technology research and development funded by ERDA, as well as a procedure for determining when and how much of such monitoring is appropriate. The guidelines cover effluent and ambient monitoring for coal gasification, coal liquefaction, magnetohydrodynamics, fluidized bed combustion, combined power cycles, coal-oil slurry combustion, and in situ gasification. They are also potentially applicable to physical and chemical coal cleaning and flue gas desulfurization. The guidelines do not address OSHA monitoring, process monitoring, the monitoring of socio-economic effects, or the monitoring of raw material resource extraction, unless such extraction is an integral part of the technology under development. Environmental monitoring is required for two basic reasons, the first related to compliance with federal, state, and local laws and regulations, and the second related to the programmatic aspects of developing environmentally acceptable ways of using coal. It is desirable for ERDA to demonstrate, through monitoring, that it is in compliance with all applicable standards and regulations in order to promote public acceptance of advanced coal technologies. Such monitoring will permit ERDA to protect the public health, safety, and welfare by modifying plant operations if ambient environmental conditions produced by a given plant exceed tolerable limits.

Schweimanns, H.R.; K.H. Dutz. Method of Discharging Residues From a Pressurized Gasification Chamber. (to Shell International Research Maatschappij B.V.). 30 Nov 1976. p. 8.

A method is described of discharging residues resulting from gasification of fuel in a chamber filled in a lower portion thereof with water and having a gas cushion at high pressure above the water level, in which the residues accumulation in the chamber are discharged through a sluicing container connected to the lower end of the chamber and conveyor means connected to the sluicing chamber.

Statnick, R.M.; L.D. Johnson. Measurement Programs for Environmental Assessment. (Industrial Environmental Research Lab., Research Triangle Park, NC). Jun 1976.

The current energy shortage and the public's demand for environmentally safe energy conversion processes have focused the attention of both the public and the private sectors on the potential environmental problems which are associated with these technologies. An environmental assessment test strategy has been developed by the Process Measurements Branch, Industrial Environmental Research Laboratory, Research Triangle Park (IERL/RTP). The proposed environmental assessment sampling and analytical test strategy consists of two distinctly different levels of effort. Level 1 is a survey phase which identifies the pollution potential of all process feed, product, and waste streams through chemical and biological testing. The second level of effort, Level 2, is characterized by quantitative determination of potentially hazardous substances in process streams and by expanded bioassay of the process streams which were sampled. This paper describes the features of this environmental assessment sampling and analysis strategy and its associated costs.

Thomas, R.S.; R.C. Lo. Application of High-Pressure Liquid Chromatography (HPLC) and Gas Chromatography (GC) to the Analysis of Polycyclic Aromatic Hydrocarbons in Fossil Fuel Conversion Processes. (Air Pollution Control Directorate of Fisheries and Environment, Ottawa). Dec 1977.

The use of high pressure liquid chromatography for separation and determination of polynuclear aromatic hydrocarbons is described. The advantages and limitations of this system are discussed and its use coupled with mass spectroscopy as an improved technique is described.

Wiesner, P.; F. Woehler, H.M. Stoenner. Process For the Treatment of Phenol-Containing Waste Water From Coal Degassing or Gasification Processes. 3 Aug 1976. p. 8.

Dissolved organic compounds in waste water resulting from coal degassing or gasification processes are removed by extraction with a solvent which is substantially water-immiscible. The solvent residues in the waste water are removed by inert gas scrubbing, and CO_2 , H_2S and NH_3 in the waste water are removed by heating and steam contacting. NH_3 is effectively removed in a steam gas/liquid contacting column by feeding the condensed head product of the column back to the top portion thereof, withdrawing a portion of the condensate from the column at a level intermediate between the top and bottom portions of the column, treating the condensate in admixture with waste water containing CO_2 , H_2S and NH_3 in a deacidification gas/liquid contacting column, and feeding the sump product of the deacidification column to the first column at a region below at which the condensate is withdrawn but intermediate between the top and bottom portions of the NH_3 -removal column.

COAL GASIFICATION-GENERAL INFORMATION

Proceedings of the Seventh Synthetic Pipeline Gas Symposium. (American Gas Association, Inc., Arlington, Va.; Energy Research and Development Administration, Washington, D.C. (USA); International Gas Union, London, England (UK)). 1976. p. 456.

Eighteen papers on various aspects of coal gasification were abstracted separately. Four other papers have been abstracted previously.

Proceedings of the Eighth Synthetic Pipeline Gas Symposium. (American Gas Association, Inc., Arlington, Va.; Energy Research and Development Administration, Washington, D.C. (USA); International Gas Union, London, England (UK)). 1976. p. 572.

Separate abstracts were prepared for 18 papers on various aspects of coal gasification. Six other papers were abstracted previously.

Workshop Proceedings on Ceramics for Energy Applications. (Battelle Columbus Labs., Ohio (USA)). 1975. p. 324.

Workshop proceedings are presented on materials for coal gasification, advanced batteries, MHD, and coal liquefaction. A separate abstract was prepared for each of eleven presentations.

Preparation of a Coal Conversion Systems Technical Data Book. Final Report. October 31, 1974--April 30, 1976. (Institute of Gas Technology, Chicago, Ill. (USA)). 1976. p. 620.

This report consists of an abbreviated outline of 10 sections that will form the content of the proposed Data Book. Priorities for work in the various sections are being assigned according to the most pressing need. The report consists of three sections. The first is the annual report for 1975. This is a format to provide a precursor to the Coal Conversion Systems Technical Data Book. It is adaptable to inclusion in a loose-leaf ring binder. The second and third sections of the report are a quarterly report for the first calendar quarter of 1976 and a monthly status report for April 1976. The last two portions are not in Data Book format inasmuch as they do not yet represent work that has been accomplished to the necessary extent.

Anthony, D.B.; J.B. Howard. Coal Devolatilization and Hydrogasification. (Massachusetts Inst. of Tech., Cambridge). (Jul 1976).

The fundamental understanding of coal and its behavior under gasification conditions is far from complete, but significant insights into the complex chemical and physical phenomena have been achieved. This review of available fundamental information focuses on thermal decomposition of coal in inert gas and in hydrogen, with emphasis on the effects on yield of products exerted by time, temperature, heating rate, pressure, hydrogen partial pressure, and particle size, and on the development of chemical and transport models of engineering importance.

Batchelder, H.R.; H.W. Nelson. Fuel Chemistry 1940--1960. (Battelle Memorial Inst., Columbus, OH). (1974).

As a part of the program on "Fuel Chemistry--Mid-Century Perspective," this paper deals with the chemistry and engineering related to fuels in the period 1941 to 1960. The state of the U.S. and of the world with respect to fuels production and reserves are reviewed to establish the ambience in which fuels work was undertaken, and the motivation for such work. Research and development of the gasification of coal, purification of the synthesis gas, developments in the Fischer-Tropsch synthesis and the high pressure hydrogenation of coal are reviewed and discussed. Studies of the structure and reactions of coal, the thermodynamics and kinetics of reactions involved in the conversion of coal are also covered insofar as they relate to the development work. The discovery of large reserves of petroleum and natural gas in the Middle East reduced the urgency of this work and efforts during the late fifties were sharply curtailed.

Berkowitz, N. Coal Gasification: A "State-of-the Art" Review. pp 30-82 of In Fuel gases from coal. New York; MSS Information Corp. (1976).

After reviewing the early work on coal gasification (mostly done in Germany and Britain to get a more flexible chemical feedstock than coal tar), the gasification reactions, heats of reaction and temperature and pressure constraints (temperatures at which the reactions are fast enough, produce more of the desired products, capital cost savings by operating at high pressure and efficiency, with definitions) are discussed. The necessity of first producing a low-Btu (or synthesis) gas, purifying it and then methanating it (with careful temperature control) to produce high-Btu gas is explained. A number of more promising second-generation gasification processes being developed for commercial application are described briefly, mentioning significant aspects and advantages. Finally, the raw material (coal, water, oxygen, power) and manpower requirements of a large gasification plant, the predicted economics of such plants, and current plans for such plants in the USA are described briefly. The possibilities of producing low-Btu gas in surface plants and by in situ gasification for power plant fuels are discussed briefly.

Biallas, M.J. (ed.). Proceedings of a Conference on Mathematical Modeling of Coal Conversion Processes. (Energy Research and Development Administration, Washington, D.C. (USA)). 16 Nov 1976. p. 310.

Nine papers were abstracted and indexed separately.

Bowden, J.R. Status of and Need for New Coal Gasification Technology. (Conoco Coal Development Co., Stamford, CT). pp 129-134 of In Proceedings of the Third Annual UMR-MEC Conference On Energy: Energy Crisis, An Evaluation of Our Resource Potential. Morgan, J.D. (ed.). North Hollywood, CA; Western Periodical Co. (1977).

Movement toward a domestic coal-based energy policy has been barely perceptible since the Arab oil embargo of 1973-1974. Rapidly declining supplies of natural gas for small businesses and residential uses can be supplemented by coal gasification or replacement of gas by coal as a power-generating fuel. At this time it probably is the better choice to use coal to generate power instead of gas. Second-generation coal gasification processes under development with ERDA financial help will not change this balance in the next 10 years, if at all.

Cavagnaro, D.M. Coal Gasification and Liquefaction Technology. Volume 3. June 1976--April 1977 (a bibliography with abstracts). (National Technical Information Service, Springfield, Va. (USA)). May 1977. p. 125.

Techniques and processes of the conversion of coal to gaseous and liquid chemicals are cited in this bibliography. It also includes solvent refined coal liquids and coal derived fuels. Coal desulfurization, cleaning, or preparation which does not involve conversion to gas or liquid fuels, or in situ combustion (underground gasification of coal deposits) are not covered. (This updated bibliography contains 120 abstracts, all of which are new entries to the previous edition.) Coal Gasification and Liquefaction Technology. Vol. 2. 1974-May, 1976.

Delannoy, G. Future Use of Coal in Energy Generation. (Cent d'Etud et de Rech des, Charbon de Fr). (Aug 1977). (In French).

During the last 15 years the oil has largely replaced the use of coal for power generation. A review is given about the reasons for a large interest in utilization of coal for heating and steam generation. An evaluation is given of the present methods for gasification of coal in situ and hydrogenation of coal.

Elliot, M.A. Fuels 1924--1940. (Texas Eastern Transmission Corp., Houston, TX). (1974).

The period 1924 to 1940 may be characterized as the flowering era of fuel science and technology. In the field of combustion this period saw the extensive development of the burning of pulverized coal under slagging conditions to generate steam; a greatly improved understanding of the kinetics and mechanism of the combustion of solid fuels. Coal gasification technology was advanced: by the development of gasifiers using oxygen; by operating at elevated pressure, under slagging conditions, and with a fluidized bed; and by demonstrating the feasibility of hydrogasification. During the period the efficient by-product coke oven almost completely replaced the beehive oven for producing metallurgical coke. Coal liquefaction and solvation progressed from the laboratory to the full-scale commercial plant. The Fischer-Tropsch process was discovered just prior to the period under discussion and it too progressed to the commercial stage during this period. Major advances were made in knowledge of the kinetics and mechanism of the oxidation of gaseous fuels and in knowledge of the properties of fuel-air mixtures. Extensive work was done on the chemical constitution of coal and tar and on their physical properties. This latter work led to the establishment of many ASTM standards. These impressive accomplishments in fuel science and technology are discussed.

Franke, F.H. Summary Report on Coal Gasification. (Rheinische Braunkohlenwerke A.G., Loeln (Germany, F.R.)). 1975. p. 2. (In German).

By means of numerous illustrations, a total survey of the actual problems in coal gasification is given. The following problems are outlined: a) The basic conversions, the kinetics, the energy demand, b) the conventional German and American processes, c) the nuclear coal gasification process now under discussion, d) the schematics of test plants under construction, e) economical considerations and estimates as well as f) main research topics.

Field, J.H.; R.T. Eddinger, Ann Arbor. 168th National Meeting of the American Chemical Society, Division of Fuel Chemistry. Atlantic City, New Jersey, September 8--13, 1974. Volume 19, No. 3. MI; Xerox University Microfilms (1974). p. 217.

Ten papers are included for which separate abstracts and indexing were prepared.

Fleming, D.K.; H.S. Primack. Purification Processes for Coal Gasification. (Institute of Gas Technology, Chicago, Ill. (USA)). 1976. p. 33.

Coal gasification is being developed to utilize the U.S. coal deposits to satisfy increasing energy requirements. Coal can be gasified to produce a high-Btu pipeline-quality gas; a low-Btu gas suitable for direct combustion or for use in combined-cycle power generations or a synthesis gas for use as a petrochemical-type feedstock. Consequently, more than a score of coal conversion processes are currently under development. In all of these processes, some undesirable components must be removed from the gas prior to end use. Because literally dozens of processes are now available for impurity removal, the selection of the optimum purification system becomes a major task. A review of purification processes for gas streams generated in high-Btu coal gasification processes is presented. Special attention is directed to systems for sulfur removal and recovery from the raw product gas and for cleaning up Claus plant tail gas.

Freedman, S. Overview of the Government's Programs in Coal Conversion and Utilization, Research, and Development. 1976.

The Coal Conversion and Utilization Program currently has more than 100 contracts outstanding. The total value of these contracts is better than \$400 million. Over 25% of this amount is contributed by industry. The present standard for cooperative joint funding is one-third private and two-thirds federal for pilot plants and fifty-fifty for demonstration plants. Participants include many elements of American industry: oil and gas companies, chemical companies, coal companies, architectural engineering and manufacturing companies, utilities, universities, research centers, and trade associations. In addition to the contractors performing major project work, highly qualified contractors are carrying out engineering evaluations, system studies, planning studies, and environmental analyses. Several interagency agreements have been established. There are in effect international agreements with the United Kingdom, Russia, Poland, and Germany. We are constantly advised of work in the private sector and adjust our planning accordingly. We cooperate with both American industry and American utilities through the AGA and EPRI to develop national plans that integrate privately sponsored and federally sponsored R and D. The federal government is now accepting responsibility for assisting the transfer of this technology into commercial reality. A national goal has been provided and appropriate financial incentives to support that goal have been worked out. We have good funding and the support of both the executive and the legislative branches of our federal government. The nation has abundant coal resources sufficient to meet national energy requirements well into the long-term era, thus providing an energy bridge to the future.

Hendel, F.J. (ed.). Monograph on Alternate Fuel Resources. Volume 20. North Hollywood, CA; Western Periodicals Co. (1976). p. 469.

The monograph is based on papers presented at the symposium. Most papers were updated to June 16, 1976. Eight papers were presented in the initial general session, followed by 6 papers in session on synthetic fuels. Five papers in Session III on gas turbine and diesel oil alternates were followed by the presentation of 8 papers on oil shale retorting in the next session. Eleven papers on alternates to gasoline in Session V were followed by 4 papers on gas and oil utilization in Session VI. The session on pollution consideration in alternate fuels (4 papers) was followed by 12 papers in a final session on fuel and energy from solid waste and biomass. Five papers were processed previously.

Huffstetler, J.K.; L.W. Rickert. Conversion Processes. Apr 1977.

Coal is a versatile energy source; it can be burned to produce heat, gasified and upgraded to possibly produce a useful pipeline gas, or liquefied to produce a fuel like a crude petroleum and used as a substitute for it. In converting coal to a gaseous fuel, sufficient hydrogen must be added to the approximately 75% carbon--5% hydrogen content ratio in coal to create a gaseous mixture that will burn with an acceptable efficiency. The problems of sulfur removal, corrosion and erosion of materials, and disposal of wastes must also be resolved. Low- and medium-Btu gasification systems vary widely in engineering design, and a single system that clearly demonstrates superiority has yet to appear. High-Btu systems involve upgrading the product to produce a high-methane gas which can be intermingled with or directly substituted for natural gas. Although successfully demonstrated in pilot plants, a catalytic methanation system has not been used in a large-scale commercial facility. Interest also has been revived in in situ gasification of coal, where coal is ignited underground and partially gasified using pressurized air and steam. Current coal liquefaction projects are based on either pyrolysis or dissolution of the coal: pyrolysis involves decomposition by heat of the organic substances in coal and collection of the volatile matter; the dissolution process involves dissolving coal in a suitable solvent under high temperature and pressure. Several conversion processes produce more than one type of product (fuel gas, coal liquid or a solid char). For some uses the products must be upgraded and purified or refined by methods similar to those used in refining petroleum. The status of the various projects is reviewed with the aid of flowsheets.

Hundemann, A.S. Pollution and Environmental Aspect of Fuel Conversion (a bibliography with abstracts). Report for 1964--Mar 1976. (National Technical Information Service, Springfield, Va. (USA)). Mar 1976. p. 92.

Abstracts dealing with environmental impacts related to fossil fuel conversion processes (primarily coal gasification) are presented. A few citations concerning environmental considerations pertaining to future energy growth are included. (This updated bibliography contains 87 abstracts, 38 of which are new entries to the previous edition.)

Gausse, P. Coal Gasification. (Aug 1977).

According to a report by the European Communities Commission, a third of the Common Market's energy requirements in the year 2000 would be covered by gas products and it would not be possible to attain this proportion with natural gas only, whether of Community origin or imported. One possible solution would be to convert solid fuel into high Btu gas, or SNG. Describes the production of SNG from coal: first generation and American industrial products (Lurgi process). In the second generation, the principal problem to solve and the processes where research has made most progress towards the production of SNG from coal are described. Presents a diagram of the chief processes for coal gasification now at an advanced stage of research in the USA. The use of nuclear heat is discussed. A special case of underground gasification, in which the process occurs at shallow depths (200/300 metres) has virtually already been proven, but gives rise to certain drawbacks (gas leakage and water pollution). However, gasification at great depth could avoid these drawbacks and such schemes are being studied in the USA, in Belgium and in Federal Germany.

Gwinn, H. Progress in the Field of Gasification and Hydrogenation of Coal: Literature Survey. (Dec 1977). (In Polish).

References published in a number of countries are discussed.

Katzman, H. Research and Development Program for Catalysis in Coal Conversion Processes. Final Report. (Libby (W.F.) Labs., Los Angeles, Calif. (USA)). May 1974. p. 408.

The use of catalysts in coal conversion processes is reviewed, and a research and development program is recommended for catalysis in future conversion technology. Emphasis is on those processes leading to clean fuels for electric power generation. The argument of the text consists of a series of articles on the subject of catalysis, including catalysts for hydrosulfurization and liquefaction of coal, and catalysts for low-sulfur producer gas for power stations, commensurate the treatment and the catalytic properties of coals--specifically the beneficial modifications by additives.

Also reviewed are Fischer-Tropsch catalysts to produce jet fuel and methanol for peaking power. An article on Lewis acid ($ZnCl_2$) catalytic liquefaction is analyzed, followed by a consideration of supporting research including the mechanism of bond breaking in coal catalysis, and center ring cracking of polynuclear aromatic structures, and lastly a review of new catalyst materials. A literature survey containing abstracts of more than 400 relevant publications is included, many of which are summarized.

Lee, B.S. Current Activities in Coal Gasification R and D. (Institute of Gas Technology, Chicago, Ill. (USA)). 1976. p. 13.

Current activities in coal gasification research and development are presented as an overview of new developments in this important area.

Lee, B.S. Overview of Coal Conversion Processes. (Institute of Gas Technology, Chicago, Ill. (USA)). 1977. p. 12.

From an instrumentation and control standpoint, there seems to be no requirements for measuring temperatures, pressures, or flow quantities that exceed the bounds of present knowledge. The problem is applying these primary process parameter measurements to environments of reasonably high temperature and pressure, combined with a potentially corrosive gaseous atmosphere. Adapting suitable materials to serve as containers for the measuring elements would allow these measurements to be taken satisfactorily. The measurement of derived process parameters, such as bed levels, bed densities, or solids circulation rates, can be adapted from pressure differential measurements or other primary process parameters, although improvements are always desirable. From a severity standpoint, instrumentation, developed for high-Btu gas operation, should be operable for all coal conversion processes. Although advances in instrumentation and control technology are always desirable and anticipated, unlike nuclear energy development (with the demands posed by radioactivity), or the space program (with demands of extreme reliability under remote control) coal conversion does not present any new dimensions for instrumentation and control.

Lee, B.S. Second-Generation Production Technology. (Institute of Gas Technology, Chicago, Ill. (USA)). 1978. p. 7.

Second-generation coal technologies have been reviewed. In high-Btu coal gasification the slagging Lurgi, COGAS, and HYGAS processes are in the demonstration plant design stage, each with a pilot plant supporting that design effort. On the pilot plant scale, in West Germany, pilot plants are either being built or are in operation for testing the high pressure version of Lurgi, Winkler, Koppers-Totzek, and Otto-Rummel processes. In the U.S. the BIGAS, Synthane and Steam-Iron processes are in pilot plant operation. Other process concepts are in the bench-scale or laboratory-scale stage. Other than coal, processes are being developed which can move into the pilot plant stage by 1979, including the PEATGAS

process for producing SNG from peat and the hydrotreating process for converting oil shale to SNG, a process particularly attractive for developing the eastern or Devonian shale resource. For western shale, the Tosco and Paraho processes are available as well as the hydrotreating process. The production of SNG from biomass is still in the early stage. However, this represents a potential area for meaningful future development.

Littlewood, K. Gasification: Theory and Application. (Univ. of Sheffield, Eng.). (1977).

Processes for the gasification of coal, oil shales and various petroleum feedstocks are reviewed in depth: history, chemical reactions, thermodynamics, and brief descriptions of particular processes. The production of hydrogen, ammonia, methanol and other chemicals from synthesis gas are discussed. Simplified flowsheets are given in many cases.

Loeding, J.W.; J.G. Patel. Coal Gasification Review. (Institute of Gas Technology, Chicago, Ill. (USA)). 1975. p.22.

At present coal gasification appears to be an attractive means of producing an alternative, nonpolluting source of energy. Once this conclusion is accepted, there are several options which need to be considered. Low Btu gas will be chosen for local and power uses, while high Btu gas will be necessary for pipeline distribution (to minimize distribution costs and use the existing nationwide system). In making either of these gases there exist several options. Many gasification processes are being developed and nine are described briefly, with flowsheets. The particular gasification process chosen will be dictated by the specific need at the time of selection, considering the user's assessment of the technological development of the various process options. Economics, the assumed feedstock, and desired operating options will be weighed heavily. Combined-cycle gas turbine-steam turbine power generation probably holds the greatest potential for the use and higher efficiencies than conventional coal-fired steam cycles. Many studies have been concerned with combining conventional steam-and gas-turbine power cycles into systems that yield a greater overall efficiency than the individual steam- or gas-turbine systems.

McBride, J.R. Low BTU Gasification: An Annotated Bibliography of the Technology. (Montana Energy Advisory Council, Helena (USA)). Jan 1977. p. 45.

This report consists of an annotated bibliography of recent literature related to low Btu gasification. It is not all-encompassing but it does give an indication of the scope and content of the extant literature. All of the information contained in this report was abstracted directly from the cited literature and no particular

effort was made to paraphrase the contents of the annotated citations. This report is designed to be a guide for the interested researcher who wishes to further pursue the technology of low Btu gasification! No attempt was made to synthesize or critically review the contents of the articles; however, the annotations do reflect the interests of the author and the interested reader should review the original article for further information and technical details.

McGhee, R.M. Coproduction of Methanol and SNG From Coal: A Route to Clean Products From Coal Using "Ready Now" Technology. (Transco Energy Co., Houston, TX). (1975).

A brief evaluation is presented of technologies that are ready now, with brief comments on their thermal efficiency and capital cost. New processes and new technology not yet proven on a commercial scale are outside the scope of this paper. A discussion is presented on what are believed to be the best opportunities for full-scale commercial plants that could be on stream as early as five years from the date of approval to proceed. A proposed plant which would produce both SNG and methanol from coal is defined. This includes the processing configuration, the capital and operating costs, and the required sales price to assure a profitable venture.

Mills, G.A. Advances in Fuel Chemistry 1961--1974. (Office of Coal Research, Washington, DC). (1974).

While major changes occurred in the amounts (50 percent increase), the greatest change was in character of fuels technology. A turnaround to a deficit supply of gas and oil brought new attitudes. New environmental concern caused major changes, e.g., switch from coal for electricity. While nuclear grew tenfold, less than two percent of U.S. energy was nuclear in 1974. Two major breakthroughs in petroleum refining were use of molecular sieves and bimetallic reforming catalysts. Hydroprocessing advanced to include petroleum residue. Petrochemical changes were many, e.g., products by pyrolysis and use of homogeneous catalysts. Research for conversion of coal to clean gas and liquid fuels took a quantum jump--seven large pilot plants were constructed to test new technology. Focus was on sulfur reduction chemistry, catalysis and engineering. Production of fuels from Athabasca tar sands began. Oil shale technology included in situ retorting, molecular structure studies, and upgrading of products. Related fuel chemistry was also important--combustion to minimize pollutants and also stack gas scrubbing.

Percival, G. Coal Gasification Developments at Westfield. (International Gas Consultancy Ltd., Stanford, CT). 1976.

Following a brief review of the principal reactions concerned in the conversion of coal to a gaseous fuel and the conditions under which they can take place, the work that has been pursued at the

Westfield Development Center of the British Gas Corp., located in Scotland, since 1973 is described. This development work has been sponsored from the outset by various groups of North American companies and distributors of clean energy, together with the American Gas Association and the Office of Coal Research (now part of ERDA). The British Gas Corp. has been active in the development of high-pressure coal-gasification technology for many years and although the corporation no longer relies upon coal for its gas supply, the technology that was developed in the past and shelved when oil products and natural gas became available is now being applied to help solve some of the problems that attend the reintroduction and expansion of coal utilization in North America. The Westfield Center is now dedicated to the development and demonstration at a significant commercial scale of processes based upon coal. It is available to operators who wish to sponsor investigations or demonstrations requiring expert technical and project management and consultancy services. The facilities at Westfield are unique, comprising a combination of coal handling, gasification and gas treatment plant with experienced research personnel capable of translating results into design.

Peterson, D.B. Coal Utilization and Conversion Technologies: State-of-the-art. (California Energy Resources Conservation and Development Commission, Sacramento (USA). Alternative Div.). Oct 1977. p. 146.

This state-of-the-art review of coal conversion and utilization technologies is intended to serve as a resource document for members of the California Energy Resources Conservation and Development Commission. As a state-of-the-art review, it is intended more as a summary of the status of major utilization and conversion technologies than as a source of detailed technical information. In the United States as a whole about 45 percent of the electrical power generation is from coal-fired plants. In California, on the other hand, only about six percent of the electricity is from coal and all of that is from coal burned outside of the State. In view of the national commitment to increased use of coal, the consideration of coal utilization and conversion technologies will necessarily be an important factor in energy planning. The purpose of this paper is to review the current status of various coal utilization and conversion technologies.

Robson, B. London. Bibliography of Literature Pertinent to the Gasification Project at CRE. Coal Research Establishment (1975).

This is a collection of literature references relevant to the current project on gasification for power generation. It, therefore, covers the subjects of gasification and combined cycles and takes in the essential topics of solids handling and gas cleaning. There is also a section on relevant symposia and meetings. The review is in no sense exhaustive or comprehensive, but should form a useful introduction to the project. The subjects of underground gasification, hydrogasification, methanation and substitute natural gas are excluded.

Rudolph, P.F.H. Art of Coal Gasification. (LURGI Mineraloeltech, Frankfurt AM, Ger). (Apr 1977).

This survey examines the various gasification systems, the three main groups of reactors, when to use counter-current or co-current operation, the influence of the ash-supplying reaction heat, as well as a description and performance data for the various processes.

Schora, F.C. Jr.; G.A. Mills. 170th National Meeting of the American Chemical Society, Division of Fuel Chemistry, Chicago, Illinois, August 24-29, 1975. Volume 20, No. 3. Chicago; American Chemical Society (1975). p. 225.

An abstract was prepared for each of 18 papers in this volume.

Schora, F.C.; W.G. Bair. Status of Coal Gasification, 1977. (Institute of Gas Technology, Chicago, Ill. (USA)). 1977. p. 7.

A review is presented of the current coal gasification program in the United States and Europe. High-pressure coal gasification processes, which are of paramount interest, are described.

Seamans, R.C. Jr.; P.C. White. Fossil Energy Program Report, 1975-1976. Volume II. Coal Gasification. (Energy Research and Development Administration, Washington, D.C. (USA)). 1976. p. 111.

In addition to an executive summary and a glossary, sections dealing with the following topics are included: Carbon Dioxide Acceptor Coal Gasification Process; Bi-Gas Process for the Generation of Pipeline Gas; Pipeline Gas by Hydrogasification (Hygas Process); Steam-Iron System for Production of Hydrogen; Synthane Process; Agglomerating Burner Process; Liquid Phase Methanation Process; Evaluation of High-Btu Gasification Products; Molten Salt Combustion and Gasification Process; Advanced Coal Gasification System for Electric Power Generation; Low-Btu Gasification of Coal for Electricity Generation; Coal Gasification Combined-Cycle System for Electric Power Generation; Low-Btu Fuel Gas; Desulfurization of Low-Btu Producer Gas; Technical and Engineering Services; The Coal Conversion System Technical Data Book; and Computer Modeling of Coal Gasification Reactors.

Shives, T.R.; W.A. Willard. MFPG Prevention of Failures in Coal Conversion Systems. (eds.). (National Bureau of Standards, Washington, D.C. (USA)). Apr 1977. p. 239.

These Proceedings consist of a group of 20 submitted papers and discussions from the 24th meeting of the Mechanical Failures Prevention Group which was held at Battelle, Columbus Laboratories in Columbus, Ohio on April 21 to 23, 1976. Prevention of failures in coal conversion systems is the central theme of the Proceedings. A series of overview lectures dealing with reliability problems in coal conversion systems, economics of failures in energy-generating

systems, corrosion, and gaps in engineering data are presented. In addition, failure analysis, materials problems, and related materials research are discussed. The papers have been abstracted and indexed separately.

Sobelewski, L.; M. Ihnatowicz. Coal Gasification to Obtain a Natural Gas Substitute (conclusion). (Główny Instytut Górnictwa, Katowice, Poland). (1976). (In Polish).

A review with 37 references covers methods of coal gasification without oxygen, such as Hygas, Acceptor, Kellogg, Union Carbide/Battelle, and Hydrane hydrogasification of coal.

Speich, P. Advanced Gasification Technologies. (Rheinische Braunkohlenwerke A.G., Koeln (Germany, F.R.)). pp vp. of In Symposium on Gasification and Liquefaction of Coal. Giesel, H.B.; W. Peters. (eds.). Essen, Germany, F.R.; Glueckauf Verl. (1976).

A review is presented on the state of development of the so-called 'advanced gasification processes' (second generation) in the USA and in Europe. The main process parameters are presented in tabular form. The gasification process using nuclear process heat (third generation) is also considered.

Speich, P. Coal Gasification: A Contribution to the Supply of Energy and Raw Materials. (Rheinische Braunkohlenwerke A.G., Koeln (Germany, F.R.)). (Sep 1976). (In German).

After a survey of those methods of coal gasification already in use on a technical scale and a status report on the processes still under development, the processes of the third generation are dealt with, whose process heat will be provided by HTR reactors. The two development lines for gasification with process heat now followed in the FRG are outlined, and the necessity of developing the HTR reactor into a safe plant for industrial use is pointed out. The firms cooperating in the project 'prototype plant nuclear process heat' are named.

Weinstein, N.J. Fundamental Data Needs for Coal Conversion Technology. Appendices. (Recon Systems, Inc., Princeton, N.J. (USA)). 7 Oct 1977. p. 437.

Inaccurate fundamental data used to design plants can affect performance and economics in ways which range from insignificant to critical. Work reported here was formulated both to detect fundamental data needs for coal conversion processes and to assess, as accurately as possible, the absolute and relative importance of those needs. Research recommendations based on this analysis include additional characterization work on coals, carbonaceous products, and coal ash; extensive characterization of coal-derived liquids and supporting research on pure compounds; experimental and theoretical studies on phase equilibria involving coal-derived liquids and gases, and pure compounds; and miscellaneous engineering studies vital to successful development of coal conversion processes.

Werner, K.G.; D Cavagnaro. Coal Gasification and Liquefaction Technology. Volume II. 1974--May 1976 (a bibliography with abstracts). Report for 1974--May 1976. (National Technical Information Service, Springfield, Va. (USA)). May 1976. p. 210.

Cited are Federally-sponsored reports on the conversion of coal to gaseous and liquid chemicals. This includes solvent refined coal liquids and coal derived fuels. It does not cover any coal desulfurization where environmental effects are involved or in situ combustion (underground gasification of coal deposits). The cleaning or preparation of coal has been excluded unless it is mentioned as part of a coal conversion process.

NUCLEAR POWER PLANT - ECONOMICS

. Fossil and Nuclear Fuel for Electric Utility Generation Requirements and Constraints, 1977--1986. Princeton, NJ; National Electric Reliability Council (1977). p. 29.

The National Electric Reliability Council has surveyed the fuel requirements for the production of electricity in the United States during the next ten years. Coal-fired generation is projected to continue to maintain its commanding role in electric power supply, averaging about 47% over the period 1977 to 1986. Nuclear generation is projected to increase its contribution to electric energy production from about 13% in 1977 to 28% in 1986, which results in nearly a four-fold increase in absolute quantity. Oil-fired generation is projected to hold its proportionate role at about 17% from 1977 through 1982 and then decrease to less than 15% by 1986. Gas-fired generation will decline by 58% over the same ten-year period from 2.6 billion MCF to 1.1 billion MCF, its proportion, however, decreasing from about 12% to 3%. Hydro generation will supply a decreasing proportion of electric power's needs, dropping from about 11 to 7% by 1986. Constraints dealing with the nation's inability to expand coal production rapidly enough and a bottleneck on its transport, the impossible demand on utilities to install scrubbers, the slowdown in the installation of light-water reactors, and regulations regarding the use of oil and gas as boiler fuels are discussed in detail.

. Analysis Confirms Nuclear Performance. (1 Jan 1977).

The availability and capacity factor of nuclear power plants and fossil fuel power plants are compared.

. Costing of Nuclear Power. (Apr 1977).

No generally accepted method for costing nuclear power has been agreed upon. Nuclear power stations also have certain cost items that do not exist for other types of power generation and should not be forgotten in a comparison of nuclear generating costs with non-nuclear generating costs. Therefore, 10 cost items that are higher in the case of nuclear power stations or do not exist in the case of non-nuclear power generation stations are discussed briefly. Some of these cost factors are not always included in nuclear power costs because such costs are borne by governments. The cost items discussed are: capital cost, repair and maintenance, capacity factor, the cost of long construction periods, insurance, land cost, disposal of radioactive wastes, dismantling nuclear power stations, protection, and training.

Why Standard Designs Fail to Speed Construction of Nuclear Power Plants. (12 Dec 1977).

Current lead times of 10 to 12 years for nuclear power plants are too long if President Carter's goal of 23 new reactors by 1985 is to be met. The paper reviews the issues concerning these long lead times. Most agree that standardization of design plans and sites is an answer to the lead-time problem. But utilities are reluctant to accept all of the standard design. Walter P. Haass of the Nuclear Regulatory Commission believes nuclear plants could be constructed in 7 or 8 years if an applicant would accept a pre-approved standard design and have early site review; licensing alone could be reduced from 18 to 6 months if standardized plans were adopted, he says. The utility industry generally approves standardization of nuclear steam-supply systems, but the other components are less-widely accepted. Plant standardization issues are presently being debated, and legislation dealing with these issues is reviewed.

Study of Advanced Fission Power Reactor Development for the United States. Volume I. (Battelle Columbus Labs, Ohio (USA)). 25 Jun 1976. p. 41.

This volume summarizes the results and conclusions of an assessment of five advanced fission power reactor concepts in the context of potential nuclear power economies developed over the time period 1975 to 2020. The study was based on the premise that the LMFBR program has been determined to be the highest priority fission reactor program and it will proceed essentially as planned. Accepting this fact, the overall objective of the study was to provide evaluations of advanced fission reactor systems for input to evaluating the levels of research and development funding for fission power. Evaluation of the reactor systems included the following categories: (1) power plant performance, (2) fuel resource utilization; (3) fuel-cycle requirements; (4) economics; (5) environmental impact; (6) risk to the public, and (7) R and D requirements to achieve commercial status. The specific major objectives of the study were twofold: (1) to parametrically assess the impact of various reactor types for various levels of power demand through the year 2020 on fissile fuel utilization, economics, and the environment, based on varying but reasonable assumptions on the rates of installation, and (2) to qualitatively assess the practicality of the advanced reactor concepts, and their research and development. The reactor concepts examined were limited to the following: advanced high-temperature, gas-cooled reactor (HTGR) systems including the thorium/U-233 fuel cycle, gas turbine, and binary cycle (BIGTGR); gas-cooled fast breeder reactor (GCFR); molten salt breeder reactor (MSBR); light water breeder reactor (LWBR); and CANDU heavy water reactor (HWR).

. Study of Advanced Fission Power Reactor Development for the United States. Volume II. (Battelle Columbus Labs., Ohio (USA)). 25 Jun 1976.

This report presents the results of a multi-phase research study which had as its objective the comparative study of various advanced fission reactors and evaluation of alternate strategies for their development in the USA through the year 2020. By direction from NSF, "advanced" reactors were defined as those which met the dual requirements of (1) offering a significant improvement in fossil fuel utilization as compared to light-water reactors and (2) currently receiving U.S. Government funding. (A detailed study of the LMFBR was specifically excluded, but cursory baseline data were obtained from ERDA sources.) Included initially were the High-Temperature Gas-Cooled Reactor (HTGR), Gas-Cooled Fast Reactor (GCFR), Molten Salt Reactor (MSR), and Light-Water Breeder Reactor (LWBR). Subsequently, the CANDU Heavy Water Reactor (HWR) was included for comparison due to increased interest in its potential. This volume presents the reasoning process and analytical methods utilized to arrive at the conclusions for the overall study.

. Final Report on Study of Advanced Fission Power Reactor Development for the United States. Volume III. (Battelle Columbus Labs., Ohio (USA)). 25 Jun 1976.

This three-volume set details a multistage research study on the comparison of various advanced fission reactors and evaluation of alternate strategies for their development in the USA through the year 2020. Volume III presents the basic data and other input information utilized in the process of the study. Detailed reactor and fuel-cycle information is contained on the HTGR, GCFR, MSBR, LWBR, and CANDU-HWR, as obtained by BCL staff from numerous sources. These data have been assembled, critically reviewed, and modified where necessary to assure consistency, both internally and for each reactor system, and between reactor types. Similar, comparative information was required for the LWR mass balances, fuel cycle, etc., but this was generally accepted from ERDA sources without the critical evaluation to which the other data were subjected. Other detailed information that relates to the objective of the study, e.g., projections of nuclear power growth and uranium availability, generic safeguards information, description of computerized models, etc., is incorporated for ready reference.

. Fossil and Nuclear 1000 MW Central Station Power Plants Investment Estimates. Final Report. (Ebasco Services, Inc., New York (USA)). Sep 1975. p. 34.

The purpose of this study is to provide estimates excluding escalation and interest during construction on a consistent basis for two fossil-fuel-fired steam electric power generating plants (coal and oil) and a nuclear electric power generating plant (nuclear light water reactor plant), each plant consisting of a single unit

having a maximum net output of 1000 MWe. The estimates were prepared on the basis of Ebasco's data and experience on other projects and are based on equivalent assumptions relative to site, labor performance and reference dates for cost data June 1975 equipment and construction costs are used. The estimates are also based on average U.S. labor rates and productivity. Adjustment factors are included for labor rates and productivity for various areas of the continental U.S., as well as the adjustments to the total plant investment for utilizing mechanical draft cooling towers, instead of natural draft cooling towers included in the basic estimates, and for providing totally enclosed steam generator building instead of steam generators being of semi-outdoor construction.

. Assessment of Energy Parks vs. Dispersed Electric Power Generating Facilities. Final Report. Volume I. (General Electric Co., Washington, D.C. (USA). Center for Energy Systems). 30 May 1975.

The General Electric Company carried out in 1974-75 a generalized assessment of the concept of energy parks, or energy centers, in comparison with the conventional practice of dispersed, distributed siting of electric generating plants. The overall objective of the study was to examine and compare the technical, economic, environmental, and institutional issues related to the energy park concept, and to identify the obstacles, benefits, and penalties that would result if the concept were adopted. Concomitant objectives were (1) identify major research and development needs, both technological and institutional, and (2) identify possible approaches to resolution of significant policy issues associated with the energy park concept. The time frame of the study assumes initial generating unit startup in 1985, and completion of construction about 20 years later. The reference energy parks of this study consist of either 20 nuclear (light water reactor) units each generating 1300 MWe for a total of 26,000 MWe or 24 fossil (coal) units, eight each of 885 MWe, 1075 MWe, and 1320 MWe for a total of 26,240 MWe. The progressively larger fossil units reflect expected growth in fossil generating facilities during the period covered by the study. The selected total capacities are larger by a factor of four or five than several evolving multi-unit generating plants and represent sizes that should reveal the potential issues, problems, and advantages associated with the energy park concept. The study was divided into nine interrelated and coordinated tasks. Volume I contains the summary, conclusions, and recommended follow on efforts. Tasks 1-4 are summarized in this volume. They are: 1 and 2, General Information for Energy Parks; 3, Transmission; and 4, Nuclear Aspects.

. Assessment of Energy Parks vs. Dispersed Electric Power Generating Facilities. Final Report. Volume II. (General Electric Co., Washington; D.C. (USA). Center for Energy Systems). 30 May 1975.

The General Electric Company in 1974-75 carried out a generalized assessment of the concept of energy parks, both nuclear and coal-fired, in comparison with the conventional practice of dispersed, distributed siting of electric generating plants. Volume I summarizes the first 4 Tasks of the study. This volume, Vol. II, summarizes the data for the final 5 Tasks: 5, Industrial Collocation; 6, Institutional Issues; 7, Environmental Overview; 8, Advanced Technologies; and 9, Comparative Assessment.

. Analyses of Power Station Economy. (Handelsministeriet, Copenhagen (Denmark)). Apr 1976. p. 96. (In Danish).

A comparison is made of construction, fuel, and other running costs of electricity production bases on conventional coal/oil-fired plants and on atomic power stations. These types of stations are selected: a 600-MW coal/oil-fired plant, a 900-MW atomic power plant of LWR type, and a 635-MW atomic power plant of CANDU type. The comparison serves to elucidate the immediate effects on social economics that the choice between conventional and atomic power production must be presumed to have for investments, fuel consumption, running costs, and consumer prices for electricity, as well as for currency costs and employment during the construction and operation of power plants.

. Action Plan to Improve Power Plant Productivity. (Mechanics Research, Inc., Los Angeles, Calif. (USA)). 22 Dec 1975. p. 65.

The report is part of a study which compared the productivity of large, above and below average, nuclear and coal-fired units to more accurately determine the underlying causes of unit reliability differences. The study evaluates the impact of management, manning, operations and maintenance factors on the measures of unit productivity/reliability. The study units were Indian Point 2 and Turkey Point 4, nuclear; and Widows Creek 8 and Bull Run, coal-fired. This Action Plan represents the culmination of the Power Plant Reliability Study performed. Presented in sections of this report are: a summary of the performance analysis of the coal-fired units; findings and conclusions of the study where the contributing factors underlying unit reliability differences are described, recommendations developed from the study results to improve the below-average unit's reliability; and a definitive step-by-step plan to improve the productivity of one of the coal-fired units.

Study on the Reliability of Large Coal-Fired and Nuclear Power Plants. Factors Affecting Power Plant Reliability. Volume I. Final Report. (Mechanics Research, Inc., Los Angeles, Calif. (USA)). 15 Dec 1975. p. 113.

The study consisted of a comparative evaluation of 2 nuclear units (Indian Point 2 - Consolidated Edison of New York, Turkey Point 4 - Florida Power and Light Company) and 2 coal-fired units (Bull Run and Widows Creek Unit 8 - Tennessee Valley Authority). The purpose of the study was to identify and assess the underlying causes of unit reliability and the causes of the observed differences in reliability performance of the units. Recommended actions for improving the reliability of one of the study units was to be presented in a format useful to other utility companies for improving reliability of their generating units. The emphasis of the study was on the aspects of management, manning, operations, and maintenance which had a significant impact on unit reliability. Volume I includes a summary, a description of the major findings from the comparative evaluation, conclusions based on these findings, and recommendations for improving the reliability of the below average units.

Study on the Reliability of Large Coal-Fired and Nuclear Power Plants. Factors Affecting Power Plant Reliability. Volume II, Final Report. (Mechanics Research, Inc., Los Angeles, Calif. (USA)). 15 Dec 1975. p. 111

The study consisted of a comparative evaluation of 2 nuclear units (Indian Point 2 - Consolidated Edison of New York, Turkey Point 4 - Florida Power and Light Company) and 2 coal-fired units (Bull Run and Widows Creek Unit 8 - Tennessee Valley Authority.) The purpose of the study was to identify and assess the underlying causes of unit unreliability and the causes of the observed differences in reliability performance of the units. Recommended actions for improving the reliability of one of the study units was to be presented in a format useful to other utility companies for improving the reliability of their generating units. The emphasis of the study was on the aspects of management, manning, operations, and maintenance which had a significant impact on unit reliability. Volume 2 presents a discussion of the comparative analyses performed for the coal fired units.

Study of the Reliability of Large Coal-Fired and Nuclear Power Plants. Factors Affecting Power Plant Reliability. Volume III. Final Report. (Mechanics Research, Inc., Los Angeles, Calif. (USA)). 15 Dec 1975. p. 103.

The study consisted of a comparative evaluation of 2 nuclear units (Indian Point 2 - Consolidated Edison of New York, Turkey Point 4 - Florida Power and Light Company) and 2 coal-fired units (Bull Run and Widows Creek Unit 8 - Tennessee Valley Authority). The purpose of the study was to identify and assess the underlying causes of unit unreliability and the causes of the observed differences in reliability performance of the units. Recommended actions for

improving the reliability of one of the study units was to be presented in a format useful to other utility companies for improving the reliability of their generating units. The emphasis of the study was on the aspects of management, manning, operations, and maintenance which had a significant impact on unit reliability. Volume 3 presents a discussion of the comparative analyses performed for the nuclear units.

. Action Plan for Improving Power Plant Productivity.
(Trident Engineering Associates, Inc., Annapolis, Md. (USA)). 17 Dec 1975. p. 56.

The operation, maintenance management, and manning of two large fossil-fueled electrical generating units and two large nuclear-fueled units are evaluated. The two units to be examined in each category were to consist of one unit with a recent history of above average reliability and one unit with a history of lesser reliability, as measured by available industry statistics. The objective of the study was to determine the underlying causes of high and low reliability in comparable plants; and to make recommendations having the potential to produce a meaningful increase in the productivity of lower performing generating units. This Action Plan is derived from information developed during the course of the study. The purpose of this Action Plan is to provide visibility to the industry as a whole of some methods which can be used as a basis for improving plant reliability, as well as to provide a guideline plan for the improvement of the reliability of the particular plant selected.

. Power Plant Productivity: An Assessment of Outages at Two Coal-Fired and Two Nuclear Plants. (Trident Engineering Associates, Inc., Annapolis, Md. (USA)). 17 Nov 1975. p. 225.

The results of a study which assessed the operation maintenance, management and manning of two large fossil-fueled electrical generating units and two large nuclear-fueled units are presented. The two units to be examined in each category were to consist of one unit with a history of high reliability, and one unit with a history of lesser reliability. The objective of the study was to find, insofar as possible, the differences between high and low reliability in similar plants; and through an understanding of these 'root' causes, to make recommendations having the potential to produce a meaningful increase in the productivity of lower performing generating units.

. Reactor Safety Study. An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants. Appendix II. Fault Trees. (Nuclear Regulatory Commission, Washington, D.C. (USA)). Oct 1975. p. 602.

Information is presented concerning fault tree analysis; fault tree quantification; parametric studies of the effect of repair on long term failure probabilities; PWR fault trees; and BWR fault trees.

Akhtar, S.M. Cost Economics of Nuclear Power Plants in the U.S. (1974).

The cost economics associated with the nuclear power plants is examined with a simplified approach to provide some insight into the complexity of evaluating nuclear fuel costs. Also described are the direct and indirect costs in 1973 dollars (and 5 kW magnitude) as they have developed since 1963, and cost trends for the future are predicted.

Bald, M. Impact on the Employment Situation of the Construction and Operation of Power Plants. (Oct 1977). (In German).

The Deutsches Institut fuer Wirtschaftsforschung (German Institute for Industrial Research) has assessed the impact on the labor situation arising from the construction of nuclear power plants and hard-coal-fired power plants, respectively, in two studies. The approach used involved a breakdown of production into various branches of industry and a conclusion, from production through labor productivity in the respective branch, to the manpower requirement corresponding to the respective productions.

Bassett, C. High Cost of Nuclear Power Plants. (27 Apr 1978).

Retroactive safety standards were found to account for over half the costs of a nuclear power plant and point up the need for an effective cost-benefit analysis of changes made by the Nuclear Regulatory Commission after construction has started. The author compared the Davis-Besse Unit No. 1 construction-cost estimates with the final-cost increases during a rate-case investigation in Ohio. He presents data furnished for ten of the largest construction contracts to illustrate the cost increases involving fixed hardware and intensive labor. The situation was found to repeat with other utilities across the country even though safeguards against irresponsible low bidding were introduced. Low bidding was found to continue, encouraged by the need for retrofitting to meet regulation changes. The average cost per kilowatt of major light-water reactors is shown to have increased from \$171 in 1970 to \$555 in 1977, while construction duration increased from 43.4 to 95.6 months during the same period.

Behling, D.J. Jr.; W. Marcuse, J. Likachinski, R. Dullien. Long-Term Economic and Environmental Consequences of Phasing Out Nuclear Electricity. (Brookhaven National Lab., Upton, N.Y. (USA)). Jun 1977. p. 102.

This study is one of a series of studies prepared by different modeling groups for Resources for the Future concerning the potential energy/economic/environmental impacts that would result from a policy decision to halt any further construction of nuclear power plants. Wherever possible, each modeling group used the same set of model input-parameter values to estimate the impacts. This study is based on the use of an integrated modeling system incorporating the Data Resources Inc. Long-Term Interindustry Transactions

Model (LITM), the Brookhaven Dynamic Energy System Optimization Model (BESOM), and several groups of interface equations. This model system is first described and then used to estimate four alternative energy/economic/environmental futures. In the Base Case scenario, it is assumed that growth in the nuclear sector will not be constrained by safety or security considerations, so that, when economical, nuclear reactors will build up at reasonable rates, including advanced uranium and breeder reactors, starting in 2000. In each of three alternative scenarios, future nuclear capacity is limited to that capacity which is either currently in operation or under construction, while coal production is permitted to expand, at most, by 5.4%/yr, 7.2%/yr, and 3.0%/yr.

Belyaev, V.I.; G.G. Karpov, I.N. Nigmatulin, E.A. Polyanskii. Effect of Land Value on Construction Costs of Thermal and Nuclear Power Plants. (All-Union Corresp. Polytech Inst., USSR). (Oct 1976). (In Russian).

A method of capacity optimization (CO) of thermal power plants (TPP) and nuclear power plants (NPP), depending on the land values (L) in the zones where they are situated, is worked out. CO's of pulverized coal, gas and fuel oil-fired TPPs and NPPs for the costs of L (thousands of roubles per hectare) equaling 10, 30, 60, 120 are determined. The necessity to take into account the costs of L when determining the capacity of TPPs with artificial reservoirs when L costs equal or exceed R. 10,000/ha, as well as for TPPs not requiring artificial reservoirs and for NPPs when they equal or exceed R. 30,000/ha, is demonstrated.

Beran, F.G. Availability and Outage Frequency of Repairable Parallel Unit Systems. (Canatom Ltd., Montreal. Quebec (Canada)). Jan 1975.

The application of reliability and maintainability analysis to the design of Gentilly-2 resulted in the evaluation of a method for analyzing a system consisting of two 100% units in parallel. Several methods were investigated of analyzing a system consisting of two 100% units in parallel, including binomial expansion, state transition methods, and numerical analysis for solution of the state transition model. As the number of simplifying assumptions decreases the number of states in which a system can be increases rapidly and analytical solution of the state transition model becomes impractical. The development of a computer program is described, which eliminates all the assumptions. Examples are given of its capabilities.

Bertman, L.; D. Cox, G. Lamb, J. Morris, J. Pfeffer, M. Rivas. Benefit-Cost Evaluation of the ERDA Fossil Energy Combustion and Advanced Power Development Program. (Mitre Corp. McLean, Va. (USA)). Jul 1976. p. 183.

The objective of this benefit-cost evaluation is to assess the implications of the investment of Federal funds in the ERDA/Fossil Energy Combustion and Advanced Power Development (CAPD) Program. Technologies considered in this study include five "Advanced" systems that will be competing in the electric utility market for new base- and intermediate-load generating capacity by the year 2000. Life-cycle busbar costs of electric power for each system are calculated, based upon estimated performance and cost characteristics. Market shares by region and year are estimated for the systems, and the benefits associated with the projected Federal RD and D investment are determined by comparison of nationwide electric power generating costs for alternative scenarios. The scenarios are distinguished by assumptions relative to the technologies considered, the price of coal, the electric energy demand, and the nuclear market share.

Bethe, H. Energy Problem. (Cornell Univ., Ithaca, NY). (1976).

After reviewing the availability and cost of world energy sources, fossil and nuclear fuels, hydro, solar, wind, and geothermal, and the applicability of these resources to U.S. electric power requirements in the future, it is concluded that the U.S. must develop nuclear energy, and, in particular, nuclear power reactors which are more conservative in the use of uranium. The thorium thermal breeder reactor with heavy water moderation is suggested as the best source of energy in the U.S. for the next 50 years.

Blake, C.; D. Cox, W. Fraize. Analysis of Projected vs. Actual Costs for Nuclear and Coal-Fired Power Plants. (Mitre Corp. McLean, Va. (USA)). Sep 1976. p. 39.

At the request of ERDA Fossil Energy, MITRE collected and analyzed available data on projected and actual power plant costs for nuclear and coal-fired systems. A total of twenty-seven references were found to contain relevant data. Included were the annual FPC reports on Steam-Electric Plant Construction Costs and Annual Production Expenses, several of the WASH reports (including WASH-1345) published by the AEC, and ERDA/AEC forms HO-254 which report nuclear plant capital cost data. Data on projected and actual capital costs for specific coal-fired plants were obtained via direct contact with individual utilities. MITRE then tabulated the projected and actual costs data, identifying plant type, size, on-line date, and the data for which the cost estimates are appropriate. The objectives of this brief study were: (1) to compare projected and actual costs for both nuclear and coal-fired power plants for start of operation dates in the period 1967 through 1975, (2) to compare cost projection accuracy for nuclear and coal-fired power

plants; and (3) to examine, in particular, projections vs actual costs for a common start-of-operation date, allowing for variable construction start dates due to the difference in construction time for the two types of power plants.

Boeck, H. Comparison of Failures in Fossil and Nuclear Power Stations. (Atominstitut der Oesterreichischen Hochschulen, Vienna). (Aug. 1976). (In German).

The regulations governing the compulsory reporting of fault incidents in power stations in various countries are considered, and a comparison is made between the faults per GWhour in American nuclear power stations and in Austrian fossil power stations. The faults are analysed, also, in respect of their origins in various components of the power stations.

Boer, H.A. Centralized or Decentralized Electricity Production. de. 1975. (In Dutch).

Because of low overall efficiency in electric power generation, it is argued that energy provision based on gas, combined with locally decentralized electricity production, saves for the Netherlands slightly more fossil fuel than nuclear technologies and makes the country independent of uranium resources. The reason the Netherlands pursues this approach is that a big part of the energy is finally used for heating in the normal or moderate temperatures.

Boyer, V.S. Economics of Nuclear Power. (Philadelphia Electric Co.) (1976).

A comparison of costs associated with building and operating nuclear, coal-, and oil-fired electric generating plants in the Philadelphia Electric system indicate an economic advantage for nuclear facilities. A breakdown of average total costs shows 1.2 cents per kilowatt-hour for nuclear, 1.7 cents for coal, and 3.3 cents for oil. The advantage for nuclear is expected to increase in the future as all fuel and capital costs escalate. Ten-year estimates compare capital and fuel costs of 1100-megawatt generating units in order to make projections of costs per kilowatt-hour for the three fuels. Although nuclear fuels are assumed to be recovered and reprocessed, the projections indicate that nuclear plants would still have the advantage if this were not the case. Known reserves of uranium will last through 1990, but the use of breeder reactors could make the domestic uranium supply nearly unlimited.

Brewer, S.T. Quantification and Comparison of External Costs of Nuclear and Fossil Electrical Power Systems. (Energy Research and Development Administration, Washington, DC). pp 506-530 of In Energy and the Environment Cost-Benefit Analysis. Karam, R.A. (ed.). Elmsford, NY; Pergamon Press, Inc. (1976).

Impacts of producing electrical energy by fossil (coal, oil, gas) and nuclear (LWRs, HTGRs, LMFBRs) systems are quantified and normalized to the annual operation of one 1000-MWe nominal unit operating at 75 percent capacity factor. Pro-rated impacts of supporting fuel cycle activities are included. Where possible, impacts are reduced to dollar costs in order to render dissimilar quantities comparable and, possibly, additive.

Charroppin, P. Is There a Cost Price for the Heat Produced From Electro-Nuclear Power Stations. Is Thermodynamic Equivalence an Economic Trap. (Cold Regions Research and Engineering Lab., Hanover, N.H. (USA)). Feb 1977. p. 9.

The thermodynamic equivalence between heat and electricity, when used uncritically and carelessly translated into a price equivalence, can effectively hide a very formidable economic 'trap' and the advantage it appears to indicate for heat production at relatively low temperatures is to be distrusted; in many cases, this advantage may be of little importance in comparison with the disadvantages of low temperatures for transportation and storage.

Chu, N. Indicator for the Economic Application of Nuclear Technology. N.Y.; Murphy, G. (Iowa State Univ., Ames). (1977).

From Iran conference on the transfer of nuclear technology; Persepolis/Shiraz, Iran (10 Apr 1977).

DeLozier, R.C. Monte Carlo Error Analysis of Power Plant Capital Cost Calculations. (Oak Ridge Gaseous Diffusion Plant, Tenn. (USA)). Apr 1977. p. 81.

A Monte Carlo statistical code is coupled with the CONCEPT capital cost estimating program to illustrate the accuracy of the cost estimates. The CONCEPT program is used to estimate the capital cost of nuclear and fossil-fueled power plants. Knowing the accuracy limitation of these estimates is important for decision-making. This analysis was made only on nuclear (PWR) type power plants in the South. However, the intent of the study was only to indicate the method of analysis, not to be a detailed sensitivity analysis of all parameters.

Diel, R. Present and Future Nuclear Power Financing Schemes. (Dresdner Bank A.G. Duesseldorf (Germany), F.R.)). (Dec 1977). (In German).

The financial requirement of nuclear power plants in the Federal Republic of Germany for the period up until 1985 was estimated to run up to some DM 100 billion already in the Nuclear Energy Study published by the Dresdner Bank in 1974. This figure is not changed in any way by the reduction the nuclear power program has suffered in the meantime, because the lower requirement for investment capital is more than offset by the price increases that have occurred meanwhile. A capital requirement in the order of DM 100 billion raises major problems for the power producing industry and the banks which, however, are not going to hamper the further expansion of nuclear power, because new financing schemes have been specially developed for the nuclear field. They include financing by leasing, the use of funds from real estate credit institutions for long term financing, borrowing of long term funds in the Euro market, and financing through subsidiaries of the utilities. The new financing schemes also apply to the large financial requirement associated with the nuclear fuel cycle, waste management in particular. In this sector the utilities agree to bear the economic risk of the companies implementing the respective projects. Accordingly, financing will not entail any major difficulties. Another area of great importance is export financing. The German-Brazilian nuclear agreement is a model of this instrument.

Eichholz, G.G. Cost-Benefit and Risk-Benefit Assessment for Nuclear Power Plants. (1976).

A cost benefit assessment is an essential part of the Environmental Impact Statement submitted as part of the licensing considerations for a nuclear facility. Such an assessment forms part of the initial decision to build a nuclear facility, enters critically into the selection of a suitable site, and ultimately forms part of the design procedures to optimize engineering solutions to deal with waste-heat dissipation, treatment methods for radioactive effluent control, and land and site use. Whereas the initial decision usually can be made in purely economic terms, the latter stages involve environmental and social issues that are not readily quantified and involve a qualitative judgment of what constitutes the least readily achievable impact. The radiological impact of the plant on the surrounding population from the release of low-level effluents can be quantified and treated as a financial "cost." Alternatively it can be treated as a "risk" and related to other risks modern man is subjected to and can be used as a means to establish site boundaries. Both cost-benefit and risk-benefit analyses represent essentially optimization approaches to the problem of making nuclear power plants economically competitive, socially and politically acceptable, and as safe or innocuous as one can reasonably make them.

Fadilah, S.M. Discounted Average Supply Probability: A New Concept in Power System Planning. (Univ. of Alexandria, Egypt). (Jun 1978).

Farmer, A.A. Nuclear Fuel Cycle. Pt. 4. The Reactors. (UKAEA Reactor Group, Risley). (Oct 1977). (In German).

The basic concepts of the reactor types now in commercial operation or to be realized before 1990 are described in the form of a survey. In the framework of a description of special features and differences, the typical parameters of the reactors are listed for comparison.

Ford, A.; H.W. Lorber. Methodology for the Analysis of the Impacts of Electric Power Production in the West. Executive Summary of the First Annual Report. (Los Alamos Scientific Lab., N.Mex. (USA)). Jan 1977. p. 27.

This report describes the progress achieved in the first year of a project to develop methodologies for analyzing the impacts of electric power production in the West. The project objective is to design a computer-based tool to help decision makers analyze some of the crucial environmental, social, and economic impacts--particularly the following impacts which involve conditions that are unique to the West: the boom town impacts that result from the construction and operation of power plants new small, isolated towns in the sparsely populated West, and the reduction in visibility caused by the fossil-fuel emissions from per plants operating in the pristine West. Additional impacts that have been addressed include public health effects from fossil-fuel pollutants, occupational health and safety, and the risk of accidental release of radioactive pollutants from nuclear power plants. The scale along which most of these varied impacts are compared is dollars. As an example, the report includes a demonstration showing how the methodologies can be used to calculate impacts associated with the 1985 expansion plan of the electric utilities belonging to the Western Systems Coordinating Council.

Fujii, H. Analysis of Economical Comparison of Nuclear and Thermal Power Generation. (International Atomic Energy Agency, Vienna (Austria)). pp 247-280 of In Genshiryoku hatsuden kaihatsu suishinjo no shomondai. Tokyo, Japan; Fuji International (1976). (In Japanese).

In the economic comparison of nuclear and thermal power generation, power cost must be compared after the present construction cost is examined, its future cost is predicted, and fuel expense is estimated. It is necessary for the comparison of construction cost that the progress is first looked back from the start of development of nuclear poer generation to the present. First, this review describes on the construction cost in the United States and also touched on the tendency of its escalation. Next, the construction cost in Japan is mentioned, where the construction cost of existing

nuclear power plants was yen80,000 to yen90,000 per kW, while that of thermal power plant was yen30,000 to yen50,000 per kW. Since these values are supposed to be the data based on the estimation around 1972, the changes of expenses for personnel and raw materials should be taken into account. The case of publishing power cost is rather rare even for light water reactor plants, and the calculating procedures are not equal among countries. Though the preconditions for calculating the power cost of nuclear power plants in Japan are complicated, it is able to say that the power cost has been approximately yen2.5 to 3.2 per kWh, while that of thermal power plants has been yen2 to 3 per kWh. However, re-evaluation is required because of the sudden rise in fuel oil cost. References for the calculation procedures of nuclear fuel cost and examples of the trial calculation are given.

Garribba, S.; A. Ovi. Statistical Utility Theory for Comparison of Nuclear Versus Fossil Power Plant Alternatives. (Cent Studi Nuci Enrico Fermi, Politec di Milano, Italy). (Jun 1977).

A statistical formulation of utility theory is developed for decision problems concerned with the choice among alternative strategies in electric energy production. Four alternatives are considered: nuclear power, fossil power, solar energy, and conservation policy. Attention is focused on a public electric utility thought of as a rational decision maker. A framework for decisions is then suggested where the admissible strategies and their possible consequences represent the information available to the decision maker.

Gauzit, M.; R. Fuhrmann. Cost of Nuclear Power Stations; Comparison Test Between France and the United States. (Novatome Industries, 92 - Le Plessis-Robinson (France)). (1977). (In French).

A comparison, even if roughly made, between the investment costs of nuclear power stations quoted in literature for France and the United States cannot be made with certainty. While in the United States the amounts correspond to the total expense in standard currency, in France they are applicable only to an estimate intended to justify a development at the level of national planning by comparing its profitability with different schemes (coal power stations, hydraulic plants, or new energies). It is shown how the shift of a factor close to 2 between two amounts found in the literature is due to different accounting practices that have been taken into account and to the differences in the inflation rates.

Gibbs, P.; P. Kalas. Feasibility Study. (Motor-Columbus Ingenieurunternehmung A.G. Baden (Switzerland)). 1975. p. 24.

The feasibility study itself examines the technical, economic and financial implications of a nuclear power station in depth so as to make sure that nuclear power is the right course to take. This means that it is quite an expensive operation and it is to avoid wasting this money that a pre-feasibility study is carried out. This preliminary study should eliminate cases where the electrical system cannot absorb the capacity of a nuclear station of commercial size, where other sources of power such as hydro-electricity, gas or cheap coal would make nuclear obviously uneconomic or where no suitable sites exist. If this first rather simple survey shows that nuclear power is a credible solution to a utilities need for electricity or heat production plant, then the next stage is a full feasibility study.

Guntay, S. Investigations of the Unit Generation Costs of the Nuclear Power Plants. (International Atomic Energy Agency, Vienna (Austria)). 1977. p. 8.

An extensive study has been carried out to investigate the unit generation costs of different reactor types. The study analyzes the following: 1) development of capital costs, 2) fuel cycle costs, 3) operation and maintenance costs, 4) local and foreign finance requirements for an arbitrary reactor type.

Hardie, R.W.; J.H. Chamberlin. Analysis of Electrical Power Generation Costs. (Hanford Engineering Development Lab., Richland, WA). (Apr 1977).

The relative competitiveness of nuclear and coal plants is assessed by dividing the U.S. into 21 regions and using a computer model to calculate costs for each plant in each region. Scenarios were considered in which resource depletion and environmental considerations affect coal generation costs. Analysis shows that if coal prices are constant in real terms and if SO₂ scrubbers are not required, nuclear plants produce electricity less expensively than coal plants in 45 percent of the country (adjusted for generation size). When either coal prices rise in real terms or when scrubbers are required, nuclear plants have the advantage in more than 90 percent of the market. In addition, sensitivity studies show that uncertainties in forecasting uranium and coal prices produce the largest difficulty in accurately comparing nuclear and coal electrical generation costs.

Hoge, J.B. Monte Carlo Simulation Used for Nuclear Power Plant Economic Evaluations. (Babcock and Wilcox Co., New York (USA)). (1976).

In this article the computer code EVANC (Evaluation of Nuclear Costs) is described, which enables cost evaluations of nuclear power plants to be made through the use of probability analysis (Monte Carlo method). With EVANC the cumbersome sensitivity analysis normally used to measure the effect of changes in input variables is avoided.

Holy, Z.J.; H.J. Zech. Approach to Sensitivity Analysis of Reactor Strategy Calculations. (Gesellschaft fuer Kernforschung m.b.H., Karlsruhe (F.R. Germany)); Stocks, K.J. (New South Wales Univ., Kensington (Australia). School of Nuclear Engineering). (1976).

The paper describes a method of obtaining, with the aid of a mathematical model, a uniform mathematical expression which takes account of the relative importance of the most important economic parameters and their interaction in reactor strategy calculations. Linear programming techniques are used for optimizing system generation costs over a given period of time. The influence of the capital cost of various reactor types is investigated as an example.

Hillebrand, G.; H. Holzer. Application of Reliability Analysis for Safety Estimation of Nuclear Power Stations. (Oesterreichische Studiengesellschaft fuer Atomenergie G.m.b.H., Seibersdorf. Forschungszentrum). (Nov 1976). (In German).

After introductory remarks about earlier uses of reliability analysis in electronics and in rocket systems, and its particular suitability for approving nuclear reactors, some judgement criteria and concept definitions are given, together with information on evaluation methods and input data for fault tree analysis. Practical examples include the GKT flow system principle and the fault tree flow system. Reference is made both to determinability and probability methods, the latter as an extension of the former. Importance of setting a level of risk acceptable to the public is stressed.

Hubert, E.H. Availability: A Particularly Important Notion for the Economic Evaluation of Nuclear Power Plants. (Union des Exploitants Electriques en Belgique, Brussels). (1976). (In French).

Some important concepts of availability, utilization and different mathematical models of nuclear power plants are reviewed. The part of the availability in the evaluation of manufacturing cost and the different factors affecting the availability are considered, as well as some operational results.

Huff, L.W. Energy and Changing Economic Considerations of Developing Countries. (Richard J. Barber Associates, Washington, DC). (Nov 1976).

From Transactions of the American Nuclear Society 1976 international meeting; Washington, DC, USA (14 Nov 1976).

Hull, A.P. Criteria for Risk Acceptance: A Health Physicist's View. (Brookhaven National Lab., Upton, N.Y. (USA)). 1977. p. 4.

A controversy over the safety of nuclear energy has grown in the U.S. since about 1970 and has now spread to near worldwide proportions. This controversy has been fueled by a variety of issues. Initially in the U.S. the most prominent issue concerned the degree of hazard of low-level radiation, in particular that associated with the nuclear fuel cycle. Since then, attention has shifted successively to the reliability of emergency core cooling systems, the longevity of nuclear wastes, the possible misuse of radioactivity by terrorists and the potential for diversion of nuclear-power-produced plutonium to weapons fabrication. Underlying each of these issues has been the implication that the employment of nuclear power will entail an unacceptable risk to the public. A reasonable perspective in this regard is a yearly risk of 1×10^{-6} compared to the level of natural hazards such as earthquakes, floods, hurricanes, and tornados. Following a satisfactory demonstration of the safety of nuclear energy, hopefully the nuclear argument could be terminated. Society could then move on to the real issues affecting energy, population and quality of life.

Iljas, J.; A.J. Surjadi. Generation Cost of a Nuclear Power Station in the Eighties and its Comparison to Other Electricity Generating Plants. (National Atomic Energy Agency, Jakarta (Indonesia)). (Dec 1975). (In Indonesian).

The various factors which are significant to the capital cost of a nuclear power plant are being reviewed. An example is given of the calculation of the power generation cost for a 600 MW nuclear power plant, which was assumed to become operational in 1985. The calculation was based on the contributions from capital cost, fuel cost and the cost for operation and maintenance. A similar calculation was carried out for a coal-generation and an oil-generation plant of the same size (600 MW) which are becoming operational in the same year (1985). The generation cost for the Saguling Hydro Project, which will be completed in 1982, is also given. This 1982 figure has been subsequently extrapolated to 1985 in order to include the effect of escalation. The result of the study could be considered as a confirmation of the Nuclear Power Planning Study for Java Island, which has been carried out at the IAEA Headquarters in Vienna in the beginning of 1975.

Knecht, P.D.; D.L. Prideaux, R.R. Zahner. Productivity Improvement Action Plan. (Nuclear Services Corp., Campbell, Calif, (USA)). 28 Nov 1975. p. 95.

The productivity of four large central station electric power plants is analyzed. Aspects of operation, maintenance, organization, or equipment operation and repair, that cause one unit to have better productivity than another are determined. Conclusions identifying the underlying causes of lost productivity and recommendations for improving plant productivity are made.

Kumar, P. Economic Considerations in Selecting a Nuclear Versus Coal-Fired Plant. (Jacobs Engineering Co., Pasadena, CA). pp 142-147 of In Energy LA; tackling the crisis. Robinson, J.W. (ed.) North Hollywood, CA: Western Periodicals Company. (1976).

In recent years, multifold costs of crude oil and natural gas have created new awareness for the cost of energy. This has left primarily nuclear power and coal-fired plants to compete for providing future sources of energy. The economic considerations for selecting a nuclear power plant versus coal-fired plant are discussed.

Lee, Y.T.; G.E. Apostolakis. Confidence Bounds for the Top Event Unavailability of Fault Trees. (Univ. of California, Los Angeles). (Jun 1976).

From Transactions of the American Nuclear Society 1976 annual meeting; Toronto, Canada (13 Jun 1976).

Lee, Y.T.; G.E. Apostolakis. Probability Intervals for the Top Event Unavailability of Fault Trees. (California Univ., Los Angeles (USA). School of Engineering and Applied Science). Jun 1976. p. 102.

The evaluation of probabilities of rare events is of major importance in the quantitative assessment of the risk from large technological systems. In particular, for nuclear power plants the complexity of the systems, their high reliability and the lack of significant statistical records have led to the extensive use of logic diagrams in the estimation of low probabilities. The estimation of probability intervals for the probability of existence of the top event of a fault tree is examined. Given the uncertainties of the primary input data, a method is described for the evaluation of the first four moments of the top even occurrence probability. These moments are then used to estimate confidence bounds by several approaches which are based on standard inequalities (e.g. Tchebycheff, Cantelli, etc.) or on empirical distributions (the Johnson family). Several examples indicate that the Johnson family of distributions yields results which are in good agreement with those produced by Monte Carlo simulation.

Lindell, B. Quantifying the Costs and Benefits of Energy. (Statens Stralskyddsinstitut, Stockholm (Sweden)). Jun 1975. p. 21.

A number of principles which have been developed for cost-benefit assessments in the radiation field are applied to the more general cost-benefit assessment of energy production. Sources of energy may be assessed in relation to a reference practice. If this is done for one and the same electricity production, the main objective is to assess detriments in comparable terms. Detriment rates may be integrated in space and time and might also be expressed in equivalent monetary units. Although there are several practical limitations to any theoretical treatment of the problem, the basic principles may form a useful background to more realistic although more complicated approaches to the task.

Lotze, C.D. Capital-Cost Behavior: Is Nuclear Different. (Nuclear Regulatory Commission, Washington, DC); Riordan, B.J. (27 Apr 1978).

The capital costs of coal-fired and nuclear power plants are found to be comparable when costs for pollution control are included. Trends in capital costs reveal a similar rate gain that retains the same economic balance. Graphs of selected cost indices are used to show that the rapid increase in direct construction costs is not unique to nuclear plants, those of hydroelectric plants as well as coal-fired having the same pattern. Comparisons of indirect capital costs, based on analyses of direct capital and total capital costs, show estimated average growth rates of total costs to be 14% for coal and 13.6% for nuclear, while direct cost growth rates are 10.2% and 10.4%. The economics of market competition can be expected to push alternative energy source projects into balance.

Mandel, H. Construction Costs - Nuclear Power Stations. (Rheinisch-Westfaelisches Elektrizitaetswerk A.G., Essen (Germany, F.R.)). pp 62-71 of In Nuclear energy maturity. Zaleski, P. (Electricite de France, 75 - Paris); Sher, R.; Mantega, M.; Gueron, J.; Williams, M.M.R. (eds.). Oxford; Pergamon (1976).

According to present development plans in the western industrial nations, nuclear power will be able to cover 35 to 45% of power requirements in the mid 1980's. Although specific investment costs are higher for nuclear power plants than for other thermal power stations, nuclear plants are in a position today to generate power more economically than fossil fired plants into the upper part of the middle load sector. The relatively high proportion of fixed costs of the total power generation costs, and a still considerable potential to exploit the economy of scale, will contribute to minimize the inflationary burden on electric power generation. Nevertheless, price development of nuclear power plants should be watched attentively, rapid price escalation for components, extremely long planning and construction times, and exaggerated environmental protection requirements which serve no real purpose may reduce the economic benefit gained by nuclear energy. Electrical utilities will try to hold investment cost down by all means; for instance, they will encourage standardization of nuclear power plants or order twin stations. For long term utilization of nuclear energy the development of high temperature reactors and fast breeders is a logical step forward.

Mattson, R. Nuclear Regulatory Commission and its Role in Environmental Standards. (Nuclear Regulatory Commission, Washington, DC). pp 680-689 of In Energy and the environment cost-benefit analysis. Karam, R.A. (ed.). Elmsford, NY; Pergamon Press, Inc. (1976).

The NRC and its predecessors in the Atomic Energy Commission represent considerable experience in environmental standards setting. The Atomic Energy Act of 1954, the 1970 Supreme Court decision on Federal pre-emption of radiation standards, the Calvert Cliffs decision of 1971, the Energy Reorganization Act of 1974, and the

Appendix I "as low as reasonably achievable" decision of 1975, to name a few of our landmarks, are representative of the scars and the achievements of being in a role of national leadership in radiation protection. The NRC, through a variety of legislative authorities, administrative regulations, regulatory guides, and national consensus standards regulates the commercial applications of nuclear energy. The purposes of regulation are the protection of the environment, public health and safety, and national security. To understand NRC's responsibilities relative to those of other Federal and state agencies concerned with environmental protection, we will briefly review the legislative authorities which underlie our regulatory program. Then we will examine the intent or the spirit of that program as embodied in our system of regulations, guides, and standards. Finally we will speak to what's happening today and what we see in the future for environmental standards.

Miettinen, J.; I. Savolainen, P. Silvnoinen. Risk-Benefit Evaluation of Nuclear Power Plant Siting. (Valtion Teknillinen Tutkimuskeskus, Helsinki (Finland)). p. 489-500 (1976).

An assessment scheme is described for the risk-benefit analyses of nuclear power versus conventional alternatives. Given the siting parameters for the proposed nuclear plant an economic comparison is made with the most advantageous competitive conventional production scenario. The economic benefit is determined from the differential discounted annual energy procurement cost as a function of the real interest rate and amortization time. The risk analysis encompasses the following factors: radiation risks in normal operation, reactor accident hazards and economic risks, atmospheric pollutants from the conventional power plants, and fuel transportation. The hazards are first considered in terms of probabilistic dose distributions. In the second stage risk components are converted to a compatible form where excess mortality is used as the risk indicator. Practical calculations are performed for the power production alternatives of Helsinki where district heat would be extracted from the nuclear power plant. At the real interest rate of 10% and amortization time of 20 yr the 1000 MW(e) nuclear option is found to be Pound9.1 m. per yr., more economic than the optimal conventional scenario. Simultaneously the nuclear alternative is estimated to reduce excess mortality by 2 to 5 fatal injuries annually.

Moraw, G.; A. Szeless. Availability of Nuclear Power Plants. (Oesterr Elektr-Wirtschaft, Vienna, Austria). (Dec 1977).

A study of nuclear power plant availability was initiated by the authors several years ago. At periodic intervals, various aspects of plant availability have been analyzed, and trends examined. The study includes 136 nuclear plants with gross electrical power of more than 100 MW(e). These plants are sited in 16 countries, and total about 80 GW(e). The study results presented in this article cover plant operations through June 1977. Several major conclusions

may be drawn from this study: (1) in mid-1977, as in previous years, no unique relationship between plant size and load factor could be shown; (2) the load factor shows an increasing trend as the number of operational years increases; (3) pressurized and heavy water reactor plants had the highest mid-1977 load factors, both reaching 68%.

Montomery, W.D.; J.P. Quirk. Cost Escalation in Nuclear Power. (California Inst. of Tech., Pasadena (USA). Environmental Quality Lab.). Jan 1978. p. 96.

This report is concerned with the escalation of capital costs of nuclear central station power plants between the early 1960s and the present. The report presents an historical overview of the development of the nuclear power industry and cost escalation in the industry, using existing data on orders and capital costs. New data are presented on regulatory delays in the licensing process, derived from a concurrent study being carried on in the Social Science group at Caltech. The conclusions of the study are that nuclear capital costs have escalated more rapidly than the GNP deflator or the construction industry price index. Prior to 1970, cost increases are related to bottleneck problems in the nuclear construction and only a minor role in cost escalation. After 1970, generic changes introduced into the licensing process by intervenors (including environmental impact reviews, antitrust reviews, more stringent safety standards) dominate the cost escalation picture, with bottlenecks of secondary importance. Recent increases in the time from application for a construction permit to commercial operation are related not only to intervenor actions, but also to suspensions, cancellations or postponements of construction by utilities due to unfavorable demand or financing conditions.

Morse, J.G. Nuclear Power: Issues and Outlook. (Colo Energy Res Inst. Golden). (Nov 1976).

A large reduction in the present U.S. dependence on imported oil will dictate more extensive use of coal and uranium for the production of electricity. There are risks associated with the use of each, but nuclear energy lies at the epicenter of the present-day environmental-energy controversy. The author examines nuclear power's five prime issues and attempts to put them into reasonable perspective. The issues are: allowable radiation release from normal reactor operation; the potential of a large-scale release; sabotage of nuclear power plants; waste disposal; and weapons proliferation. These risks are contrasted with those inherent in using coal-fired and hydroelectric plants, and it is concluded that nuclear power is by far the safest available power option.

Myers, M.L.; L.C. Fuller, H.I. Bowers. Guidelines for Estimating Nonfuel Operation and Maintenance Costs for Large Steam--Electric Power Plants. (Oak Ridge National Lab., TN (USA)). 1978. p. 16.

Nonfuel operation and maintenance costs usually are developed by escalating the current cost of existing coal and nuclear-fueled units available at the Public Information Office of the Federal Energy Regulatory Commission, formerly the Federal Power Commission. Recently, operation requirements have introduced several important cost factors which are not reflected in historical data. To provide this information, estimating guidelines have been prepared and incorporated in a digital computer program first issued in 1975. A recent update of this work has been made for nuclear plants and coal plants. These procedures relate direct maintenance to labor and materials in place of plant capital investments. Costs for staff, services, and the principal miscellaneous expense components are also quantified to obtain the annual total costs. These guidelines are designed to assist in power plant evaluations for near-term projects. Specific cases are expected to require further economic assessment.

Nair, K.; W.S. Smith, R.B. Kulkarni, A. Sicherman. Decision Analysis: A Methodology for Solving Complex Problems in the Utility Industry; Benefit-Cost Analysis, Siting, and Long-Range Planning. (Woodward-Clyde Consultants, San Francisco). (1976).

The influence of an uncertain economy, environmental regulations, public and governmental attitudes toward energy conservation and fuel availability must be considered in utility industry decisions. Decision makers must also consider, in addition to technical and economic factors, such subjective issues as aesthetics, social impacts, and ecological considerations. The acceptance of these factors as necessary to the decision-making process has had a significant impact on the complexity of the problems facing decision makers in every industry. Concepts of decision analysis are discussed, references to expository articles are presented, and the applicability of decision analysis techniques to some problems facing the utility industry is described.

Nosach, V.G.; V.T. Rogovoi. Suitability of Using Atomic Energy At Existing Thermal Electrical Power Plants. (Inst. of Tech. and Thermophysics, Kiev). (1976). (In Russian).

A thermal concept is described for the simultaneous use of atomic and organic fuels at existing electrical thermal power plants. Equations are presented for the mass and heat balances, from which a preliminary calculation of this thermal concept was carried out. The results indicate that it is efficient to use a nuclear reactor at thermal electrical power plants, as a result of which up to 50% of the total heat is produced by nuclear fuel, while the consumption of organic is decreased by almost a factor of two in this case.

O'Brien, J. U.S. Regulatory Requirements for Blast Effects From Accidental Explosions. (U.S. Nuclear Regulatory Commission, Washington, D.C., USA). (Mar 1978).

Procedures and criteria acceptable to the USNRC for verifying the adequacy of nuclear power plant structures, systems and components to resist the effects of accidental explosions outside the plant are presented. A method of computing the probability of an accidental explosion is also given. The relative importance of blast generated missiles, wind, overpressure and ground shock is treated. The inherent strength of Nuclear Power Plants to resist blast effects due to imposed design requirements for other extreme environmental loads, such as tornadoes, is considered. Shortcomings in the previous practice of comparing air blasts with tornadoes are outlined. Load combinations as well as allowable limits under blast effects are treated. Differences between USNRC requirements and those presented in Appendix C to the ACI-349 Code, 'Code Requirements for Nuclear Safety Related Concrete Structures, are outlined and evaluated.

Peelle, E. Internalizing Social Costs in Power Plant Siting: Some Examples for Coal and Nuclear Plants in the United States. (Oak Ridge National Lab., Tenn. (USA)). 1976. p. 27.

Selected aspects of the United States experience in one particular type of energy development project, the siting of nuclear and fossil fueled power generating facilities, are examined in terms of how well community-level impacts are internalized. New institutional arrangements being devised and new requirements being made at local, state, regional, and federal levels in response to these dissociations of cost and benefits from large energy development projects are discussed. Selected examples of these new institutional responses are analyzed for adequacy and significance.

Phung, D.L.; A.M. Perry, C.E. Whittle. Economics of Coal and Nuclear Electricity: A Treatment of Inflation and Differential Cost Increases. (Oak Ridge Associated Universities, TN). (1977).

The cost competitiveness between the coal and nuclear options depends on location, capital requirement, fuel supply, and environmental and safety regulations. The authors present a formulation that permits rational treatment of inflation and differential fuel cost increases. They also examined many likely scenarios that reflect the great uncertainty confronting the utility executive. Unless nuclear fuel will increase at 4 percent per year over and above increases in coal cost, or unless nuclear plants cost much more and deliver much less energy than realistically projected, the authors conclude that nuclear electricity is the economic choice for most parts of the country except in the Western coal region. In this region, coal electricity is cheaper due to low transportation cost; but if coal-fired plants in this region are also required to install SO₂ scrubbers, the competition against nuclear

electricity would follow the same pattern as in other regions. The authors further conclude that, due to institutional constraints, inflation tends to favor the high-capital, low-fuel-cost power option.

Phung, D.L. Cost Comparison Between Base-Load Coal-Fired and Nuclear Plants in the Mid-Term Future. (Oak Ridge Associated Universities. TN). Apr 1977.

The relative costs between the coal and nuclear modes of electricity generation in the period between 1985 and 2015 has been examined with the "best estimates" approach coupled with a scenario study that covers various sensitive factors. Baseline data for capital and operating costs at "beginning of life" are determined by careful examination of past, present, and short-term future trends. Estimated inflation of the economy and net fuel cost increases are internalized in the determination of life-cycle levelized cost of electricity in several plausible scenarios. Best estimates for capital costs in 1985 dollars are determined to be \$1,080/kWe, \$860/kWe, and \$700/kWe, respectively, for nuclear plants, coal-fired plants with SO₂ scrubbers. Several factors such as geographical location, construction scope requirements, and construction duration contribute to an uncertainty of 40 percent to these capital costs. Baseline nuclear fuels are estimated at \$75/lb U₃O₈ and \$150 SWU, but still result in a nuclear fuel cost at approximately half the cost of coal. Of the five typical regions of the country considered in the study (the Midwest, the Northeast, Florida and Texas, Appalachia, and the northern Rocky Mountain states), results indicate that the low-sulfur coal option is always attractive in the northern mountain states, whereas the nuclear option would be less costly elsewhere. The magnitude of cost difference between the options depend on the inflation rate of the economy and on the methods of discounting a stream of future expenditures to a fixed point in time.

Phung, D.L. Cost Comparison Between Baseload Coal-Fired and Nuclear Plants in the Midterm Future (1985-2015). (Institute for Energy Analysis, Oak Ridge, Tenn. (USA)). Sep 1976. p. 34.

The purpose of this study is to examine the relative costs of the coal and nuclear modes of electricity generation in the period between 1985 and 2015. These two modes of power generation are likely to be the mainstay source of electric power in the United States for that time period. A thorough understanding of their competitiveness not only is important in utility companies' decisions to go one route or the other but also is important to the government and the public when answers must be found for difficult questions, such as economic and environmental implications of a massive societal leaning toward one or the other option. In this study, the primary and secondary factors that affect the cost comparison of coal-fired and nuclear plant options for the midterm future have been separated and arranged so that they can be examined systematically. Estimated inflation of the economy and net

fuel cost increases are internalized in the determination of life-cycle levelized cost of electricity in several plausible scenarios. Baseline data for capital and operating costs at beginning-of-life are determined by the tax rate, the expected rate of inflation at the time of capitalization, the net rate of fuel cost increases, and future eventualities of inflation. Other factors such as plant life spans, capacity factors, changes in baseline capital, and fuel cost are considered in sensitivity studies.

Riordan, C. Local and Regional Economic Impacts of Energy Complexes. (Environmental Protection Agency, Washington, DC). pp 312-333 of In Civil and Environmental Engineering Aspects of Energy Complexes. Goodman, A.S. (ed.). New York; American Society of Civil Engineers (1976).

An attempt was made to evaluate the local and regional economic impacts of an energy complex that might be reflected in terms of income, employment, stability, and prices. First, the author addresses the generic problem of trying to explain and predict the local and regional economic impact of any major productive facility. Secondly, he discusses some of the particular problems associated with attempting to assess the impacts of power plants. Some conclusions in the latter discussion are based on the author's study of constructing and operating a nuclear power station in an upstate New York county.

Rooney, R.F.; M. Tennenbaum. Economics of Nuclear Power Plant Siting in the California Coastal Zone. (California State Univ., Long Beach). pp 133-153 of In California Energy: The Economic Factors. San Francisco; Federal Reserve Bank of San Francisco (1976).

This article is both narrower and broader in scope than the Richter paper, "Impact of Nuclear Power Moratorium on California Energy Costs." It is narrower because, strictly speaking, it compares only a coastal nuclear plant with a coal-burning plant in Utah. At the same time, it is broader in scope because it discusses certain external costs which are not included in the Richter cost-of-production analysis. This paper argues that external costs in the form of environmental damage can offset the relative advantages of nuclear power over coal measured in costs of production. However, the net benefit of coal over nuclear as shown reflects several differences in assumptions. First, the investment period is assumed to be two years longer for nuclear plants than for coal plants; where this assumption is removed, as in Richter's paper, different conclusions emerge about relative costs. Second, external social costs are considered in connection with locating a nuclear plant in California, but are generally ignored in connection with a Utah coal plant. The authors argue not only that coal-fired plants would provide a better alternative to nuclear, but also that fewer generating facilities will be required in the future than are now projected, because of such factors as the slowing growth trend of the

California economy. Thus, they conclude, there is no economic reason to commit coastal-zone resources to nuclear power plant sites within the next few years.

Rowsome, F.H. III. How Finely Should Faults Be Resolved in Fault Tree Analysis. (Bechtel Power Corp. Gaithersburg. MD). (Jun 1976).

From Transactions of the American Nuclear Society 1976 annual meeting; Toronto, Canada (13 Jun 1976).

Rudasill, C.L. Coal and Nuclear Generating Costs. (Electric Power Research Inst., Palo Alto, Calif, (USA)). Apr 1977. p. 38.

Costs of producing electricity from coal and nuclear power stations, using currently available technology, have been analyzed by the Electric Power Research Institute, based on the results of contracted studies made by several consulting organizations. The analysis was made on a regional basis to consider differences in coal characteristics, transportation differences, and labor and local material costs in various parts of the country. The major factors that affect coal and nuclear generation costs were investigated on a consistent basis. The overall results of the study indicate that: (1) both coal and nuclear generation can be economically attractive in all regions, depending on specific circumstances; (2) nuclear generation shows an average economic advantage in all regions, particularly in the east, where higher delivered coal prices prevail; and (3) any new base-load generating technology must achieve levelized busbar costs of 35 to 45 mills per kilowatt hour to compete with existing technology on an economic basis. The work has established a benchmark for evaluating other studies and provided a base for sensitivity analyses.

Rudasill, C.L. Comparing Coal and Nuclear Generating Costs. (Electric Power Research Inst., Palo Alto, CA). (Oct 1977).

EPRI reviewed and analyzed the costs of producing electricity from coal and from nuclear power stations, using available technology with current safety and environmental regulations in six regions of the U.S. The general objectives of the study were to understand the principal parameters that affect the cost of coal and nuclear generation; identify uncertainty ranges in estimates of the costs; provide a consistent set of cost estimates for generation that can be useful in making general appraisals; and establish base cost estimates that can be updated as improved data become available. Overall results show that coal or nuclear generation can be economically viable in all regions; nuclear generation shows an average cost advantage over coal in all regions; average cost positions of coal and nuclear are closer together in the western USA, reflecting the generally lower cost of coal; and a new baseload generating technology must achieve 30-year-levelized total busbar costs of 35 to 45 mills/kWh in 1976 dollars to compete with existing technology on an economic basis.

Sailer, W.F. Engineers' Contribution to Nuclear Fueled Generating Station Availability and Operability. (Jun 1976).

From Transaction of the American Nuclear Society 1976 annual meeting; Toronto, Canada (13 Jun 1976).

Salem, S.L.; G.E. Apostolakis, D. Okrent. New Methodology For the Computer-Aided Construction of Fault Trees. (California Univ., Los Angeles (USA). School of Engineering and Applied Science). (1977).

A methodology for systematically constructing fault trees for general complex systems is developed. A means of modeling component behaviour via decision tables is presented, and a procedure for constructing and editing fault trees, either manually or by computer, is developed. The techniques employed result in a complete fault tree in standard form. In order to demonstrate the methodology, the computer program CAT was developed and is used to construct trees for a nuclear system. By analyzing and comparing these fault trees, several conclusions are reached. First, such an approach can be used to produce fault trees that accurately describe system behaviour. Second, multiple trees can be rapidly produced by defining various TOP events, including system success. Finally, the accuracy and utility of such trees is shown to depend upon the careful development of the decision table models by the analyst, and of the overall system definition itself. Thus the method is seen to be a tool for assisting in the work of fault tree construction rather than a replacement for the careful work of the fault tree analyst.

Schenk, H. Availability and Causes of Incidents in Nuclear Power Stations. (Kernkraftwerk Obrigheim B.m.b.H., Obrigheim/Mosbach (F.R. Germany)). (Feb 1976). (In German).

Short communication only.

Scherer, C.R. Estimating Peak and Off-Peak Marginal Costs for an Electric Power System: An Ex Ante Approach. (Univ. of California, Los Angeles). (Aug 1976).

This paper proposes and implements an ex ante approach to estimating thermal electric power system long-run average and peak and off-peak marginal costs subject to pollution-emission constraints. Mixed-integer programming is used as a framework for a static, cost-minimizing model of system capacity and operating costs incurred in meeting loads that vary with time and geographic location. The model assumes multiple-generating technologies can be used to meet system loads. Transmission and losses are explicitly considered in this transshipment mathematical program. The model is implemented for the system of the New York State Electric and Gas Corp. Results show that peak marginal costs at a particular location in the system are three to four times system average costs and can be more than ten times as great as base-load marginal costs. Marginal

costs during a particular demand period vary by as much as 30 percent from one load center to another in the system. System overage total costs increase (with output) when new steam plants are all coal-fired, but decrease when they are nuclear-fueled. When the most restrictive pollution standards are imposed, system average total costs are approximately 25 percent higher than when no standards are imposed. These results provide substantial empirical evidence in support of the case for time-specific rates based on marginal costs.

Schmidt, G. Problem Kernenergie. Eine Kritische Information. (Problem of Nuclear Power. A Critical Information). Braunschweig, Germany, F.R.; Vieweg (1977). p. 174. (In German).

The book deals with the highly popular question of whether nuclear power plants are needed at all. The author tries to find the answer with regard to the present and the expected future situation. Economical and technical points of view are taken into consideration. The author avoids neither the problem of waste management of nuclear power plants nor the one of citizen's initiatives. This specialized book in generally understandable form is apt for use for study, for lectures and for gaining an opinion on the pros and cons of peaceful utilization of nuclear energy.

Schwarz, O. Tendencies of Modern Power Plant Development. (VGB Technische Vereinigung der Grosskraftwerksbetreiber e. V., Essen (Germany), F.R.)). pp 145-160 of In Energy supply of the future. Suler, K.J.; Scharmann, A. (eds.). Muenchen, Germany, F.R.; Thiemig (1977). (In German)

The modern power plant development is characterized by large units bivalently fuelled by solid, liquid, or gaseous fossil fuels and by large, ameliorated nuclear power stations. In 20 to 30 years gas-cooled high-temperature reactors will be at disposal, for the generation of synthetic 'natural' gas (methane), too. At long term the hydrogen economy will play an important role.

Simard, R.L. Critique of the Council on Economic Priorities Test "Power Plant Performance: Nuclear and Coal Capacity Factors and Economics". (Oak Ridge National Lab., Tenn. (USA)). 18 Apr 1977. p. 41.

The Council on Economic Priorities (CEP) has assembled capacity factor data on most U.S. nuclear and coal-fired units in operation, performed a regression analysis upon capacity factor as a function of intrinsic unit variables such as size and age, and attempted a comparison of the economics of typical nuclear and coal-fired units using the resultant fitted-capacity factors. The report points out inadequacies in the CEP data base, the lack of predictive value in the results of the regression analysis, and inconsistencies in the economic evaluation of nuclear and coal-fired units.

Smith, D.S.; Lancaster, A.A. Nuclear Power's Effects On Electric Rate Making. (Federal Energy Regulatory Commission, Washington, DC). (2 Feb 1978).

Government and the electric utility industry are re-evaluating nuclear power's contribution to the total U.S. energy supplies. This article addresses how the recently increased nuclear plant construction and operation costs are translated into the prices that consumers pay for electricity. The electric rates that consumers pay must reflect the costs of producing electricity, as well as the costs of transmission, distribution, metering, and billing. The use of nuclear power for electric production is anticipated to grow rapidly so as to meet a larger portion of our country's electricity needs through the end of the century, so nuclear power costs are expected to be an even larger portion of the total electricity price. There are certain rate-making issues that are actively being discussed in public forums and before state and Federal regulatory bodies. These issues are not unique to nuclear power, but take on added significance when nuclear power is used by utilities to produce electricity because of the technology required and because of the type, timing, and magnitude of the costs involved. These are: (1) inclusion of construction work in progress in the rate base; (2) fuel adjustment clauses and treatment of nuclear fuel cycle costs; (3) treatment of certain taxes under the rate-making method called normalization or deferral accounting (sometimes referred to as "Phantom taxes"); and (4) rate treatment for particular nuclear expense items reflecting costs of delays, plant cancellations, and operational slowdowns.

Smith, K.R.; J. Weyant, J.P. Holdren. Evaluation of Conventional Power Systems. (California Univ., Berkeley (USA)). Jul 1975. p. 194.

The technical, economic, and environmental characteristics of (thermal, nonsolar) electric power plants are reviewed. The fuel cycle, from extraction of new fuel to final waste management, is included. Emphasis is placed on the fossil fuel and nuclear technologies.

Spangler, M.B. Probabilistic Methods of Assessing Risk in Cost-Benefit Analysis of Nuclear Power Plants and Alternative Energy Sources. (Nuclear Regulatory Commission, Washington, DC). pp 446-478 of In Energy and the environment cost-benefit analysis. Karam, R.A. (ed.). Elmsfor, NY; Pergamon Press, Inc. (1976).

The licensing of nuclear power plants requires an analysis of environmental and societal impacts of alternative energy sources, sites, plant designs and the alternative of not constructing an electrical power plant at all. The evaluation of the flow of costs and benefits during a five- to seven-year construction period plus a thirty-to forty-year plant life requires forecasts to be prepared whose uncertainty of realization is itself a source of risk to

societal values. This paper discusses the nature of risk and uncertainty and explores different forecasting methodologies and their application to the future supply and demand of alternative source of energies and their diversity of impacts on public interests at the local, regional and national levels.

Sternberg, D. Substantive Law Problems in Jurisdiction. pp 49-59 of Fuenftes Deutches Atomrechts-Symposium. Referate und Diskussion-sberichte. Lukes, R. (ed.) (Muenster Univ. (German, F.R.). Inst. fuer Arbets-und Wirtschaftsrecht). Koeln, Germany, F.R.; Heymanns (1977). (In German)

Substantive law problems in nuclear licensing procedure jurisdiction are discussed. Preconditions for the right to file a suit pursuant to section 42, sub-section 2 VwGO are investigated, in the context of which the necessity is pointed out to differentiate between normal operation and possible accidents. Furthermore, comments are made on the definition of 'facility' in terms of nuclear law, the understanding of which is rather decisive for the substantial scope of the nuclear licensing procedures. Also, legal problems are examined which arise from special forms of financing for nuclear power plant projects, in particular in connection with leasing financing.

Stevens, C.A. Computation of Error Propagation in Fault Trees. (Science Applications, Inc., La Jolla, CA). (Jun 1976).

From Transactions of the American Nuclear Society 1976 annual meeting: Toronto, Canada (13 Jun 1976).

Stolyarova, I.A. Economic Efficiency of Heat Supply Based on Organic Fuel When Building Basic-Load Nuclear Condensation Power Plants. (Dec 1977). (In Russian).

The problem of the effect of the introduction of basic-load nuclear condensation power plants on the relative economic efficiency of natural gas-fired heat-and-power plants is examined. An analysis of the calculation results for the European part of the USSR shows that the combined scheme of energy supply based on organic fuel is equally economic or more effective than the separate electric power and heat production scheme when the specific reduced costs of production of electric power at nuclear condensation power plants amounts to 1.2 kopeck/kW*h) in all the comparison variant considered. If energy supply schemes are equieconomic, the combined scheme should be adopted. If specific reduced costs of electric power output at nuclear condensation power plants are cut, the separate scheme of energy supply will be more effective than the combined one.

Takeda, S.; H. Ujita, K. Matsuoka. Human Error Analysis in Nuclear Power Plants. (Atomic Energy Research Lab., Kawasaki, Japan). (1977).

From ANS winter meeting; San Francisco, CA, USA (27 Nov 1977)

Tulenko, D.M.; P.F. Ostwalk, K.D. Timmerhaus. Total Present-Worth Economic Comparison of Coal and Nuclear Fuel Energy Alternatives. (Univ. of Colorado, Boulder). pp 760-767 of In Proceedings, of the Third Annual UMR-MEC Conference On Energy: Eenergy Crisis, An Evaluation of Our Resource Potential. Morgan, J.D. (ed.). North Hollywood, CA; Western Periodicals Co. (1977).

This paper utilizes the total present-worth concept to make an economic comparison for a 500-MWe electrical-power-generating station operated either with Eastern U.S. coal, Western U.S. coal, or nuclear fuel. Arguments are presented to support the use of this concept for comparing the economic desirability of various energy alternatives used for generating electrical power.

Vienna; IAEA Economic Evaluation of Bids for Nuclear Power Plants. A Guidebook. (1976) p. 183.

The purpose of the guidebook is to assist an organization responsible for a nuclear power project in evaluating and establishing an economic order of merit among competing bids. An approximate overall time schedule for a first nuclear power plant project is provided. A schematic outline of technical bid evaluation is given. The basic procedure of economic bid evaluation is outlined, e.g. evaluation of the present worth of all cost items of plant capital investment, of the nuclear cycle, of O and M costs (operation and maintenance costs), and of economic corrections. All these cost items are evaluated for the economic life of the plant and corrected for escalation where applicable.

Waddell, J.D. Estimation, Comparison, and Evaluation of Advanced Fission Power Reactor Generation Costs. Columbus, OH; Ohio State Univ. (1977). p. 333.

The study compares the high-temperature gas-cooled reactor (HTGR), the gas-cooled fast reactor (GCFR), the molten-salt breeder reactor (MSBR), the light water breeder reactor (LWBR), and the heavy water reactor (HWR) with proposed light water reactors (LWR) and liquid-metal fast breeder reactors (LMFBR). The relative electrical generation costs, including the effects of the introduction of advanced reactor fuel cycles into the U.S. nuclear power economy were projected through the year 2030. The study utilized the NEEDS computer code which is a simulation of the U.S. nuclear power economy. The future potential electrical generation costs and cumulative consumption of uranium ore were developed using characterizations of the advanced systems. The reactor-fuel cycle characterizations were developed from literature reviews and personal

discussions with the proponents of the various systems. The study developed a ranking of the concepts based on generation costs and uranium consumption.

Watson, W.D. Jr. Economic and Environmental Consequences of a Nuclear Power Plant Phaseout. (Resources for the Future, Inc., Washington, DC). (Spr 1978).

Study groups have recently attempted to analyze the issues offered by proponents of halting nuclear power plant construction and those offered by groups in favor of nuclear energy. This paper also analyzes trade-offs, two alternative futures or scenarios for the U.S. being examined: one in which nuclear energy continues to grow at fairly rapid rates vs. one in which nuclear power plants currently operating and those actually under construction are allowed to operate for a normal lifetime but construction of any additional plants is halted. When it is possible and whenever it seems reasonable, the approach taken in this paper is to quantify the relevant trade-offs over the next 50-year period. While this time period is too short to observe the full, ultimate consequences of a nuclear energy phaseout, anything longer would reduce confidence in results to a level too low to make the effort worthwhile. The approach involves consideration of likely developments in each of the major factors that can influence the future in order to determine which assumptions are most reasonable to include in the projection exercise. These assumptions are then incorporated into a model of the U.S. economy that is run for each of the two alternative scenarios in order to estimate the relevant trade-offs. The model and key assumptions used in running both scenarios are described. Results are then compared first in terms of economic and resource impacts and then in terms of environmental impacts. Finally, trade-offs between the two scenarios are reviewed and conclusions given.

Wilson, J.R. Selecting the "Right" Common-Cause Analysis Technique. (EG and G Idaho, Inc., Idaho Falls). (1977).

From ANS winter meeting; San Francisco, CA, USA (27 Nov 1977).

Wolfe, G. Capital Cost Estimates For a Nuclear Power Planning Study. (International Atomic Energy Agency, Vienna (Austria). Div. of Nuclear Power and Reactors). 1975. p. 15.

Nuclear plant capital cost experience and estimates vary from less than 200 \$/kWe to more than 1,000 \$/kWe depending on cost reference data, unit size, site and scope of supply.

Wolf, L.; J. Olmos. Modular Approach to Fault Tree and Reliability Analysis. (Massachusetts Inst. of Tech., Cambridge). (Jun 1977).

From Transactions of the American Nuclear Society 1977 annual meeting; New York, NY, USA (12 Jun 1977).

Zener, C. Comparison of the Economics of Nuclear and Solar Power.
(Carnegie-Mellon Univ., Pittsburgh). pp 535-548 of In Sharing the Sun: Solar Technology in the Seventies. Volume 5. Boer, K.W. (ed.). Cape Canaveral, FL; American Section of the International Solar Energy Society (1976).

This paper compares the estimated capital costs per net power capacity for nuclear and for ocean thermal energy conversion plants ordered today for delivery in the mid 1980's. The estimate for nuclear plants takes into consideration the 24% annual increase in estimated costs since 1967, the historical factor of 2 of the actual cost over the estimated cost, and finally the low 56% average capacity factor for large nuclear plants, versus the planned-for capacity factor of 80%. The estimate for OTEC plants starts from estimates made by industry using only state-of-the-art components, and introducing anticipated improvements in the performance of heat exchangers. The estimates obtained in this manner give approximately \$3,000 for nuclear, approximately \$1,000/kW for OTEC generating capacity with 80% capacity factor.

NUCLEAR POWER PLANTS-ENVIRONMENTAL IMPACTS

Acceptable Risk in Reactor Safety Studies. 1975.

Acceptable risk is defined in terms of its five basic parameter: the hazard or problem; the probability of occurrence; the consequence; the possible alternative actions; and the value system of the community or the society. The problem of consistency in design at a site and between differing sites is discussed and solutions are suggested. Techniques for consistent deterministic and probabilistic setting limits and design standards are illustrated using data from AEC Reactor Safety Study, WASH-1400. The influence of level of consequence is discussed and a general methodology for decision analysis in resource allocation problems is briefly introduced and illustrated. The concept of acceptable risk is put in a quantitative format that can be used by engineers and planners. Bayesian statistical methods are introduced to develop the methodologies.

Environmental Impact Section. Apr 1977.

The Section is concerned with preparation of environmental statements and assessments and development of assessment methodologies for energy technologies. During 1976, activities involved nuclear, fossil, and geothermal energy; this work was supported by the U.S. Army, HUD, US ERDA, and US NRC. Two special studies--one on the effects of power plant intake structures on fish impingement and another on multiple uses of cooling lakes--were completed and should serve as references for future analyses. Two research projects sponsored by NRC-- the Unified Transport Approach (UTA) to Power Plant Assessment and the Environmental Monitoring Data Evaluation Study--were continued. The purpose of the UA program is to develop fast-transient, one-, and two-dimensional transport models for estimating thermal, radiological, chemical, and biological impacts in complicated water bodies. The impact of public use of various products that contain radioactive isotope is being evaluated. The Environmental Impact Sections assistance to NRC expanded to include assessments of fuel-fabrication facilities being considered for relicensing and two uranium in situ solution mining facility proposals. The work for HUD comprises an assessment of the first application of MIUS in a new town development. A generic environmental statement was prepared and an environmental monitoring program for the facility was designed.

Nuclear Power. Aug 1977.

Radiation hazards from nuclear power plants, including reactor operations, nuclear fuel preparation, and radioactive waste disposal are reviewed. Measures for the protection of the public are discussed.

Balanced Program Plan. Analysis for Biomedical and Environmental Research. (Battelle Pacific Northwest Labs, Richland, Wash. (USA)). Jun 1976.

Major issues associated with the use of nuclear power are health hazards of exposure to radioactive materials; sources of radiation exposure; reactor accidents; sabotage of nuclear facilities; diversion of fissile material and its use for extortion; and the presence of plutonium in the environment. Fission fuel cycle technology is discussed with regard to milling, UF₆ production, uranium enrichment, plutonium fuel fabrication, power production, fuel processing, waste management, and fuel and waste transportation. The following problem areas of fuel cycle technology are briefly discussed: characterization, measurement, and monitoring; transport processes; health effects; ecological processes and effects; and integrated assessment. Estimated program unit costs are summarized by King-Muir Category.

Environmental Impacts of the Generation of Electricity in the Pacific Northwest. Volume I. (Equitable Environmental Health, Inc., Woodbury, N.Y. (USA)). Sep 1976. p. 269.

The report describes and quantifies the environmental impacts of all existing plants and various scenarios for planned thermal electrical generating facilities through 1995 in the Pacific Northwest. The scope of the study includes the extraction, processing and transportation, as well as conversion of fuel for the generating facilities where these operations occur within the Pacific Northwest. Short-term and long-term, cumulative, synergistic, and regionwide impacts of a variety of types and configurations of power generation are assessed.

Environmental Impacts of the Generation of Electricity in the Pacific Northwest. Volume II. (Equitable Environmental Health, Inc., Woodbury, N.Y. (USA)). Sep 1976. p. 205.

Short-term and long-term, cumulative, synergistic, and regionwide impacts of a variety of types and configurations of power generation are assessed. The approach of this study is to focus on the pathways and effects of residuals from power generation. These residuals are the releases to, or intrusions on, the environment and include air pollutants, water pollutants, solid waste, land disturbance, and noise.

Factors Involved in Planning for Construction of Thermal Power Plants. Session II. pp 83-151 of In Thermal power conference, Pullman, WA; Washington State University (1974).

Factors involved in planning for construction of thermal power plants are delineated in five papers and a discussion session. The papers are: Controlling the Socio-Economic Impacts During the Construction of Thermal Power Plants, by Myron B. Hawkins, Woodward-Envicon, Inc., San Francisco; Energy Sources, by C. Patton, C. Patton and Associates, Rock Springs, WY; Labor Mobility, by Adson E. Starner, Portland General Electric Co., Portland, OR; Environmental Planning--An Important Facet in the Construction of Thermal Power Plants, by Kenneth R. Wise, Washington Public Power Supply System; and Uranium Enrichment--Key to Nuclear Power, by J. L. Schwennesen, Division of Production and Materials Management, U.S. Atomic Energy Commission.

Social-Economic Impacts of Power Plant Construction. Session I. pp 3-79 of In Thermal power conference. Pullman, WA; Washington State University (1974).

The socio-economic impacts of power plant construction are presented via six papers and a discussion session. The papers are: Colstrip Project, by Albert C. Tsao, Montana Dept. of Natural Resources and Conservation; Projected Social and Economic Problems Resulting From the Construction and Operation of the Skagit Nuclear Project as Seen by a Local Government Agency, by R.C. Schofield, Skagit County Planning Dept., Mount Vernon, WA.; Impact of a Major Construction Project on an Isolated Medium-Sized Community (Kennebec, Pasco, and Richland, Washington), by G.L. Wilfert and J.R. Young, Battelle--Northwest, Richland, WA.; Institutional Aspects of Thermal Power Plant Construction, by W.J. Finnegan, Puget Sound Power and Light Co.; One Individual's Thinking on Bulk Energy Siting, by Jack B. Robertson, Regional Administration, FEA, Region X; and The Project Independence Hearings--The Public Speaks, by Jack B. Robertson, Regional Administrator, FEA, Region X.

8th Annual National Conference on Radiation Control. Radiation Benefits and Risks: Facts, Issues, and Options. (Bureau of Radiological Health, Rockville, Md. (USA)). Apr. 1977. p. 428.

This publication contains the proceedings of the Eighth Annual National Conference on Radiation Control--Radiation Benefits and Risks: Facts, Issues, and Options, held May 2-7, 1976, in Springfield, Illinois. Participants representing State and major local radiation control programs, as well as Federal agencies, discussed mutual radiation control programs. The formal presentations and the reports of the various task forces and workshops are included in these proceedings.

Liquid Pathway Generic Study. Impacts of Accidental Radioactive Releases to the Hydrosphere From Floating and Land-Based Nuclear Power Plants. (Nuclear Regulatory Commission, Washington, D.C. (USA). Div. of Site Safety and Environmental Analysis). Feb. 1978. p. 397.

The staff concludes that for representative sites, there are differences in the impacts of accidental radioactive releases to the hydrosphere between floating nuclear plants (FNPs) and land-based plants (LBPs) of the ice-condenser type. The consequences of releases from design basis accidents are found to be lower for an FNP than for an LBP. For core-melt events which we consider to be of very low probability, the staff results indicate that the expected liquid pathway consequences are higher at an FNP than at an LBP, and that interdiction at the site is not likely for an FNP. The staff considers this combination of differences in release magnitude and interdiction potential to be significant. An assessment of the overall significance of the total risk associated with potential releases to liquid and airborne pathways will be considered in a forthcoming environmental impact statement for the FNP. This environmental impact statement will include a consideration of the environmental, social, and economic impacts of the operation of the FNP, as well as a value-impact analysis of alternatives which may avoid or mitigate radiological impacts to the environment.

Preparation of Environmental Reports for Nuclear Power Stations. (Nuclear Regulatory Commission, Washington, D.C. (USA)). Jul 1976. p. 99.

Guides for the standard format and content of environmental reports for nuclear power plants are presented.

Terrestrial Environmental Studies for Nuclear Power Stations. (Nuclear Regulatory Commission, Washington, D.C. (USA). Office of Standards Development). Jul 1976. p. 8.

This regulatory guide provides technical information for the design and execution of terrestrial environmental studies for nuclear power stations. The information resulting from these studies, as they relate to ecological aspects of site selection, assessment of terrestrial effects of station construction and operation, and formulation of related monitoring activities, may be appropriate for inclusion in the applicant's environmental report. Although there is a need for a thorough evaluation of environmental impacts, it is important that resources not be needlessly dissipated on programs of limited value. The need for accurate evaluation and timely review of the environmental report makes it essential to focus quickly on meaningful issues and to avoid exhaustive analyses not directly related to station impacts. This guide recommends site selection assessments, resource management, source control, and control of effects as means for protecting the terrestrial ecology. The approach recommended for terrestrial surveys begins with broadly based land-use and biotic inventories and then focuses on a limited number of significant environmental issues.

Alcohol Fuels Program Plan. (Department of Energy, Washington, D.C. (USA). Alcohol Fuels Program). Mar 1978. p. 59.

The Department of Energy has considered the production and use of ethanol and methanol as liquid fuels. The Task Force on Alcohol Fuels has reviewed the status of alcohol-related activities within DOE and elsewhere and has formulated a plan of action to (1) help resolve uncertainties, and (2) provide options supportive of potential national decisions in this area. DOE is currently conducting a fuels Supply Strategy Study which will consider all candidate alternative fuels and emphasize contingency planning to ensure an acceptable balance between supply and demand under future contingency cases. The special studies included in the Immediate Action Element will provide analyses of key-issue areas for alcohol fuels to support the fuels Supply Strategy Study. These special studies will examine the following aspects of alcohol fuels use: (1) resource availability, (2) economic, environmental, and social impacts, (3) end-use applications, (4) Federal fiscal consequences, (5) industry incentives, and (6) policy instruments for price control, market assurance, and import control. Background information and the program rationale are discussed and a comprehensive outline of the proposed commercialization studies is presented.

Adam, E.; H. Carl, M. Schwarz. Environment and the Modern Nuclear Power Plant. (Technische Univ., Dresden (German Democratic Republic). Sektion Energieumwandlung). (1976). (In German).

Environmental effects of nuclear power plants, i.e. waste heat and radioactive effluents, are briefly outlined. Safety considerations deal with the maximum credible accident and the design basis accident and lead to the conclusion that a combination of both concepts seems to be most appropriate. Reviewing the current status and trend of nuclear power plant development, it is stated that nuclear power is safe and does not affect the environment. Finally, safety engineering aspects of modern nuclear power plants with pressurized water reactors are discussed considering especially the prevention of loss-of-coolant accidents.

Adams, S.M.; P.A. Cunningham, D.D. Gray, K.D. Kumar, A.J. Witten. Critical Evaluation of the Nonradiological Environmental Technical Specifications. Program Description, Summary, and Recommendations. Vol. 1. (Oak Ridge National Lab., Tenn. (USA)). 10 Aug 1976. p. 57.

A comprehensive study of the data collected as part of the environmental Technical Specifications program for eight nuclear power plants was conducted for the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory commission. This report includes a summary of the screening phase in which the adequacy of the hydro-thermal and ecological monitoring data for each plant were evaluated, and the summary and recommendations resulting from a detailed examination of the three nuclear power plants selected in the initial screening.

Akin, E.J.; J.M. Barton, J.L. Bledsoe. Development of a Unified Transport Approach for the Assessment of Power-Plant Impact. (Oak Ridge National Lab., Tenn, (USA)). 1 Mar 1977. p. 47.

Progress during the first 18 months in implementation of the Unified Transport Approach (UTA) is summarized in this report, which covers the period through December 1976. The goal of this project is to develop mathematical models for fast-transient, one-and two-dimensional transport of thermal, radiological, chemical, and biological properties in rivers, estuaries, lakes, and coastal regions for assessing the impact of power-plant operations. Development and validation of these models are illustrated in applications at several sites where data is available. The models include submodels for sediment transport, exchange of a soluble isotope with sediment, and zone-matching models to connect near-field problems of reentrainment and recirculation with far-field convective transport. Several types of automated data preparation have been introduced, and the codes have been designed to allow input of specified plant operating conditions for given durations. The UTA provides a common basis for calculating the transport of intensive quantities that depend on basic flow properties, which can be obtained from a common set of data for geometry, bathymetry, and meteorology that must be prepared only once. The formulation and calculation are based on a stable set of algorithms that have been tested and proven valid. The user can then focus on understanding and interpreting thermal, chemical, or radiological transport results with confidence that the basic calculations are direct, efficient, and meaningful. Recent work in each of the three areas is described.

Auerbach, S.I. Impact Assessment for Nuclear Power Plants: Implications for Ecological and Environmental Sciences. (Oak Ridge National Lab., TN). pp 41-51 of In Environmental Impact of Nuclear Power Plants. Karam, R.A. (ed.). Elmsford, NY; Pergamon Press, Inc. (1976).

Some topics discussed are as follows: the need for analyses to delineate environmental pathways of radionuclide migration; the need for detailed lists of species of flora and fauna; the role of NEPA in introducing environmental considerations into decision making; responsibility of the scientific community for meeting goals of NEPA; the nature of ecology; purpose of impact statements; and cooperation from the agencies and utilities in the area of environmental assessment.

Auerbach, S.I.; D.E. Reichle, E.G. Stuxness. Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1977. ESD Publication No. 1145. (Oak Ridge National Lab., Tenn. (USA)). Mar 1978. p. 251.

Separate abstracts were prepared for the ten sections of this report. Appendices giving publications, professional activities, and organization charts are also included.

Baker, E.J.; S.G. West, D.J. Moss, J.K. Weyant. Impact of Offshore Nuclear Generating Stations on Recreational Behavior at Adjacent Coastal Sites. (Florida State Univ., Tallahassee (USA). Florida Resources and Environmental Analysis Center). Oct 1977. p. 145.

A multi-faceted investigation was undertaken to project the impact of offshore nuclear power plants on beach visitation at adjacent beaches. Related literature was reviewed concerning human adjustment to natural hazards, risk-taking behavior, and public attitudes toward nuclear power. Approximately 2400 people were interviewed at beaches in three states with respect to: intended avoidance of beaches near a hypothetical floating nuclear plant (FNP), relative importance of proximity to a FNP, when compared to other beach attributes, onshore-offshore preference for coastal nuclear plant location, behavioral impact of NRC licensing of FNPs, relative tourism impact of coastal nuclear plant compared to coastal coal-fired plant, public concerns about nuclear safety, public attitudes toward alternative energy sources, public confidence in sources of information about nuclear power, visual impact of a FNP, and knowledge about nuclear power. Four beach areas near currently operating coastal nuclear power plants were studied to assess impacts on tourism resulting from plant construction. Data suggest that proximity of a FNP is less important than other beach attributes in determining beach attractiveness, probably no more than (and perhaps less than) 5% to 10% of current beach patrons would avoid a beach after FNP siting three miles directly offshore, and impact of a FNP would decrease exponentially as distance away increased.

Ballard, R.L. Current Environmental Issues in Power Plant Licensing. (Nuclear Regulatory Commission, Washington, DC). (Jun 1978).

Bayer, A.; R. Kalckbrenner, M. Schueckler. Investigation of the Long-Term Radiological Environmental Impact Caused by an Accumulation of Nuclear Facilities. (Kernforschungszentrum Karlsruhe (Germany, F.R.). Inst. fuer Neutronenphysik und Reaktortechnik). Jun 1975. (In German).

After the incorporation of several additional atmospheric and hydrophoric transport effects the part of the computer program incorporating these effects is now nearly completed. The relevant input data like site characteristics, release rates, deposition velocities, etc. have been updated on the basis of recent reports and personal communications. Partial results of a few exposure pathways have already been obtained.

Bender, M. Economic and Environmental Balancing in Response to NEPA for Electric Power Generating Plants. (Oak Ridge National Lab., TN). pp 377-409 of In Environmental Impact of Nuclear Power Plants. Karam, R.A. (ed.). Elmsford, NY; Pergamon Press, Inc. (1976).

Classical economics offers some basic principles that can provide guidance in responding to the National Environmental Policy Act (NEPA). The principle of value interchangeability was first developed by Adam Smith in terms of trade economics, but the idea that everything has its economic price is true for environmental values as well as material values. In the NEPA framework, "reasonable price" is an objective. The requirement is to establish a quantitative means by which monetary values can be interchanged with other values so that we can determine whether environmental values have a reasonable and acceptable economic price. An attempt is made to define value systems suited to this type of quantification so that monetary and environmental values can be treated interchangeably for NEPA balancing purposes.

Bernardi, R.; B. Borko. Quantitative Environmental Comparison of Coal and Nuclear Generation Workshop Summary. (Mitre Corp., McLean, Va. (USA)). Sep 1975.

Some topics discussed are as follows: the economic and social costs of coal and nuclear electric generation; effects of emitted carbon dioxide, waste heat, and particulates on climate modification; estimation of public risks of commercial nuclear power plants; potential for diverting recycled plutonium from the nuclear fuel cycle for use in terrorism, sabotage, and political extortion; major sources of radiation releases and the effects of accidents of fuel reprocessing and recovery plants; accidents and risks from the transportation of radioactive materials; and evaluation of methods and risks for radioactive waste disposal.

Beisold, H.; P. Handge, G. Meurin. Environmental Aspects of Nuclear Power Stations. (Gesellschaft fuer Reaktorsicherheit m.b.H. (GRS) Koeln (Germany, F.R.)). (Feb 1977). (In German).

The aim of this article is to summarize the environmental aspects of nuclear power production in a condensed form and to review the potential public health problems. Radioactive material discharged to the air and into water may cause an external or internal radiation exposure to man. It is shown that the population is exposed to ionizing radiation originating from nuclear power plants to an extent which is very small compared to the natural background. Special attention is given to the use of river water for cooling purposes and the resulting heating-up of rivers. The environmental influence of cooling towers is restricted to the immediate vicinity of the site. On the basis of this review it can be stated that, compared to other industries, nuclear power plants have only a small impact on the environment.

Borsch, P.; E. Muench. The Safety of Nuclear Power Plants. Nov 1975.
(In German).

A description of the advantages of nuclear power plants producing energy is followed by a discussion of the hazards and the safety measures taken as protection against radioactive pollution. After going into possible and hypothetical accidents, a risk assessment is made in the course of which the results of the Rasmussen study are discussed as well. Finally the effects of fossil and nuclear power plants on the environment are compared with each other.

Brocksen, R.W. Ecological Analyses and Applications. Nov 1977.

Progress is reported on the following: analysis of ecological impacts of construction and operation of nuclear power plants; fossil energy environmental project; ecological analysis of geothermal energy development; HUD modular integrated utility systems; expansion of uranium enrichment facilities at Portsmouth; environmental standard review plans; environmental assessment of cooling reservoirs; and analysis of fish impingement at power plants in the southeastern United States.

Burkhard, G.A.; H. Basler. Nuclear Power Plants and Thermal Pollution of the Environment. (Jan 1976).

The thermal pollution of the environment by nuclear plants is compared with that of other power plants. Based on the fundamental laws of thermodynamics and the thermal pollution caused by the various methods of power generation, means of utilizing the waste heat from the plants for district heating are described with reference to examples. It is found that, for Switzerland in particular, the utilization of the heat from nuclear power plants could considerably reduce the consumption of fuel oil. However, since it is not always possible to utilize all the heat produced, especially in summer, it has to be dissipated by some other means. To avoid heating the rivers excessively, cooling towers may be used. A brief summary of the present technical standard of cooling towers and their effects on the surroundings is followed by theories connecting the possible influence on the climate of heat and dust caused by burning fossil fuels. In order to reduce pollution, future development will have to be largely away from fossil fuels and more towards nuclear plants combined with district heating. Naturally the availability of the primary sources of energy plays a very important part.

Burnett, T.W.T. Human Cost of Regulatory Delays. (Westinghouse Electric Corp., Pittsburgh). (Jun 1976).

Burnett, T.W.T.; D.F. Paddleford. Nuclear Power is Better for Your Health. (Westinghouse Electric Corp, Pittsburgh). (Jun 1976).

Caputo, R. Comparative Assessment of Orbital and Terrestrial Central Power Plants. (Jet Propulsion Lab., Pasadena, CA). pp 1468-1475 of Proceedings of the 12th Intersociety Energy Conversion Engineering Conference. Vol. II. La Grange Park, IL; American Nuclear Society, Inc. (1977).

Recent studies of the space power system (SPS) are integrated into a total social cost framework developed for terrestrial central electric power systems. Total social costs include the projection of commercial economics to the time frame of interest as well as the federal research, development and demonstration (RD and D) costs, the health impacts, the resources required, the environmental impacts and other social costs. The total energy system is evaluated from mining, construction, operation to deactivation. The SPS system is limited to transporting all materials from the earth's surface to geosynchronous orbit. Use of the moon as a source of materials is excluded as is use of other than geosynchronous orbit for the power satellite. Only silicon photovoltaic is considered as the SPS energy conversion technique. Costs and impacts of the LWR are considered as a reference for nuclear systems, and the low BTU coal gasification with combined cycle gas and steam turbines is considered as a reference for a fossil central electric plant. The ground solar systems considered are solar thermal using the central receiver approach with thermal storage, and solar photovoltaic using the silicon cell with battery storage. The 1985 ERDA low cost photovoltaic goal of \$0.50/W/sub peak/ is assumed to be achieved at 13 percent module efficiency. All ground plants are either designed for or operated at an annual average load factor of 0.7 baseload operation.

Carson, J.E. Atmospheric Impacts of Wet Cooling Systems for Power Plants. (Argonne National Lab. IL). (Jun 1977).

Church, H.W. Atmospheric Dispersion Model as Used in the Reactor Safety Study, WASH-1400. (Sandia Lab., Albuquerque, NM). pp 188-193 of In Third Symposium On Atmospheric Turbulence, Diffusion, and Air Quality. Preprints. Boston; American Meteorological Society (1976).

The Reactor Safety Study, WASH-1400, was published in final form in October, 1975, by the U.S. Nuclear Regulatory Commission. This study represents as complete an assessment of accident risks in the U.S. commercial nuclear power plants as the state-of-the-art permits. Appendix VI of WASH-1400, Calculation of Reactor Accident Consequences, describes the input data and mathematical models used to calculate the consequences of a potential release of radioactive material to the environment in the event of a nuclear power plant accident. The primary goal of the study was to assess risk from commercial nuclear power plants as realistically as possible in order to provide proper perspective of potential risk comparison. The objective of predicting consequences of a given radioactivity release was accomplished through construction and execution of a computerized model which accounted for the manner in which radioactivity is dispersed in the environment, the number of people

and amount of property exposed, the effects of radiation exposure on people, release characteristics, atmospheric dispersion, dosimetry, population, health effects, and property damage are shown schematically. The computer code (COMO for CONsequence MOdel), used in dose calculations, is discussed.

Comar, C.I. Health Effects of Electricity Production. (Electric Power Research Inst., Palo Alto, CA). (Feb 1977).

Comparisons of nuclear and fossil-fuel power plants indicate that other factors, such as land and water, transportation, capital, etc., besides population health effects may limit the development of power generating plants. With lag times of seven to ten years for plant construction, the U.S. needs to determine what mix of fuels, shortages, and conservation to pursue. The major barrier for coal appears to be uncertainty over the development of control technology to protect the environment when large amounts are burned. Public perceptions of nuclear risks suffer from lack of knowledge, association in the public mind with nuclear weapons, and the fact that no effects on the general public have actually been observed. Analysis of respiration, disease, and genetic effect data and possible sociological implications for the two types of plants conclude that it is easier to implement controls for nuclear power and the assumed risks of death level are lower for nuclear plants than for other technologies we are familiar with and accept.

Comar, C. Societal Impacts of Energy-Related Health Effects and Control Technology. (Electric Power Research Inst., Palo Alto, CA). (Jun 1978).

Commoner, B.; H. Boksenbaum, M. Corr. Energy and Human Welfare: A Critical Analysis. Volume I. The Social Costs of Power Production. (eds.). New York; MacMillan Information (1975). p. 237.

Statements are presented of the Board of Directors of the American Association for the Advancement of Science and the Committee on Environmental Alterations. Following the Preface by Barry Commoner, eighteen papers are presented: Thermal Pollution and Its Control by Christopher T. Hill; Biologic Effects of Air Pollution by Robert Frank; Acid Rain by Gene E. Likens, F. Herbert Bormann, and Noye M. Johnson; Environmental Consequences of Extracting Coal by Michael Fortune; Reclamation of Strip Mine Spoil Banks in Wyoming by Morton May, Robert Lang, Leandro Lujan, Peter Jacoby, and Wesley Thompson; Oil Spills by Max Buemer, Howard L. Sanders, J. Fred Grassle, and George R. Hampson; Nuclear Power: Its Promise and Its Problems by Milton Shaw; Radioactivity from Fossil-Fuel and Nuclear Power Plants by J.E. Martin, E.D. Harward, D.T. Oakley, J.M. Smith, and P.H. Bedrosian; A Reevaluation of Reactor Safety by Daniel F. Ford; Management of Radioactive Wastes from the Use of Nuclear Fuel by George Berg; Storage of High Level Radioactive Wastes by William W. Hambleton; Plutonium and Public Health by Donald P. Geesaman; Radiation: The Invisible Casualties by John W. Gofman and Arthur

R. Tamplin; The Need for National and International Systems to Provide Physical Security for Fissionable Materials by Theodore B. Taylor; and Nuclear Electric Power by Sheldon Novick.

Critchley, O.H. Risk Production, Safety Analysis and Quantitative Probability Methods - A Caveat. (Manchester Univ. (UK)). (Jan 1976).

Views are expressed on the use of quantitative techniques for the determination of value judgements in nuclear safety assessments, hazard evaluation, and risk prediction. Caution is urged when attempts are made to quantify value judgements in the field of nuclear safety. Criteria are given for the meaningful application of reliability methods, but doubts are expressed about their application to safety analysis, risk prediction and design guidances for experimental or prototype plant. Doubts are also expressed about some concomitant methods of population dose evaluation. The complexities of new designs of nuclear power plants make the problem of safety assessment more difficult, but some possible approaches are suggested as alternatives to the quantitative techniques criticized.

Cunningham, P.A.; S.M. Adams, K.D. Kumar. Evaluation of Environmental Impact Predictions. (Oak Ridge National Lab., Tenn. (USA)). 1977. p. 20.

An analysis and evaluation of the ecological monitoring program at the Surry Nuclear Power Plant showed that predictions of potential environmental impact made in the Final Environmental Statement (FES), which were based on generally accepted ecological principles, were not completely substantiated by environmental monitoring data. The Surry Nuclear Power Plant (Unit 1 and 2) was chosen for study because of the facility's relatively continuous operating history and the availability of environmental data adequate for analysis. Preoperational and operational fish monitoring data were used to assess the validity of the FES prediction that fish would congregate in the thermal plume during winter months and would avoid the plume during summer months. Analysis of monitoring data showed that fish catch per unit effort (CPE) was generally high in the thermal plume during winter months; however, the highest fish catches occurred in the plume during the summer. Possible explanations for differences between the FES prediction and results observed in analysis of monitoring data are discussed, and general recommendations are outlined for improving impact assessment predictions.

D'Angelo, L.J. A Guide to Information Resources for Nuclear Environmental Reporting. Directory Report, 1973-76. (Atomic Industrial Forum, Washington, D.C. (USA)). Feb 1977. p. 167.

A directory is presented of existing information resources, products, and services which are relevant to the environmental information reporting requirements of Federal and state regulatory agencies and to the environmental decision-making process for

energy facilities. The guide covers industrial, association, and government resources and includes descriptions of technical abstracting/indexing services and other publications, computer data banks response and referral centers, and information supermarkets. A selective listing of data bases which may be of value in the environmental reporting process for nuclear and fossil facilities with pertinent descriptive data about each is included. The guide also lists criteria to use when requesting searches and descriptions of the various products offered by the information services covered. A glossary of terminology used by the information industry is also provided.

Davis, G.J. Alternative Methods of Minimizing Fish Mortalities Due to Air Supersaturation in Thermal Discharge. (Boston Edison Co.); Krabach, M.H.; Marcello, R.A. (Jun 1978).

Desrosiers, A.E. Optimization of Radiological Environmental Surveillance Programs. (Yankee Atomic Electric Co., Westboro, MA). (Jun 1978).

Dinger, B.E. Non-Radiological Effects on Terrestrial Environs. (Oak Ridge National Lab., TN). pp 52-108 of In Environmental Impact of nuclear power plants. Karam, R.A. (ed.). Elmsford, NY; Pergamon Press, Inc. (1976).

Some topics discussed are as follows: preparation of environmental impact statements; procedures for descriptive materials; site selection for terrestrial and geological characterizations; characteristics of surface and ground waters; importance of meteorological information for evaluation of radiological and chemical impacts of nuclear stations; mammalian and avian biotic composition; transmission facilities construction program; effects of construction on land use; mitigating measures for limiting adverse construction effects; impacts on biota; and effects of closed-cycle cooling systems on the terrestrial environment.

Distenfeld, C.H.; J.R. Klemish. Monitoring of Radioiodine from Containment Accidents. (Brookhaven National Lab., Upton, N.Y. (USA)). Jul 1977. p. 20.

An air sampling system was developed that merged the useful properties of solid adsorbers, vacuum cleaner air movers, and Civil Defense GM survey meters. The system can be used to monitor the environmental levels of ^{131}I produced by release from containment accidents in nuclear power reactors.

Doyle, M.R.; M.W. Golay, N.C. Rasmussen. Comparison of Environmental Impacts of Coal and Nuclear Systems for Military Utility Application and Consequences of Reactor Accidents. Final Report. (Massachusetts Inst. of Tech., Cambridge (USA). Dept of Nuclear Engineering). Feb 1975. p. 126.

This study compares the environmental impacts of a coal district heating station and a high temperature gas-cooled reactor total energy system. In addition, the consequences of nuclear accidents

are predicted. Radioactive, chemical and thermal emissions from the two plants are determined and methods of control are discussed. The costs of control systems are estimated from a variety of sources including current prices provided by manufacturers. The consequences of nuclear accidents are predicted by use of the computer model developed for the Wash 1400 Reactor Safety Study of the Atomic Energy Commission. This model predicts the number of acute deaths, illnesses, cancers, and genetic diseases and the monetary cost which would be expected from the worst possible accident at the nuclear plant.

Eckerman, K.F.; R.S. Stowe, N.A. Frigerio. Argonne Radiological Impact Program (ARIP). Part II. MONITOR: A Program and Data Base for Retrieval and Utilization of Pollutant Monitoring Data. (Argonne National Lab., Ill. (USA)). Feb 1977. p. 116.

The Argonne Radiological Impact Program (ARIP) is an ongoing project that aims at developing methodologies for assessing the carcinogenic hazards associated with nuclear power development. The current report (Part II) treats the storage and access of available data on radiation and radioactivity levels in the U.S. A computer code (the MONITOR program) is presented, which can serve as a ready-access data bank for all monitoring data acquired over the past two decades. The MONITOR program currently stores data on monitoring locations, types of monitoring efforts, and types of monitoring data reported in Radiation Data and Reports by the various state and federal networks; expansion of this data base to include nuclear power facilities in operation or on order is ongoing. The MONITOR code retrieves information within a search radius, or rectangle, circumscribed by parameters of latitude and longitude, and lists or maps the data as requested. The code, with examples, is given in full in the report.

Ellett, W.H.M.; A.C.B. Richardson. Estimates of the Cancer Risk Due to Nuclear-Electric Power Generation. (Environmental Protection Agency, Washington, D.C. (USA). Office of Radiation Programs). Oct 1976. p. 39.

The cancer risk from the uranium fuel cycle for nuclear power plants is estimated and some of the issues concerning the degree of uncertainty in such risk estimates are discussed. The estimated risk of fatal cancer for the various portions of the uranium fuel cycle was calculated. If the risk per gigawatt from accidents and waste disposal are as low as seems likely now, about one cancer death could be committed for each gigawatt-year of electrical energy produced.

Endres, G.W.R. Radiation Dose to Construction Workers at Operating Nuclear Power Plant Sites. Annual Report, August 1976-July 1977. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Jan 1978. p. 83.

Radiation exposures received by most construction workers at nuclear power plant sites have not been measured routinely because field surveys have indicated exposure levels below the point for which monitoring is required. As a consequence, the dose to individuals and groups of workers is not known to the degree desired for adequate environmental impact assessment. This study was developed to measure and evaluate radiation exposure and exposure rates received by construction workers at various reactor sites where one or more reactors are operating while construction is proceeding on one or more additional reactors. This study is providing a data base from which a realistic assessment of radiological impact can be made for the construction workers of proposed multiunit nuclear power plants and to help arrive at a decision as to whether increased control of the radiation exposure of these workers is warranted. Four nuclear sites were included in this study after receiving approval of the operating utilities. Data from thermoluminescent personnel dosimeters and environmental dosimeters showed that the construction workers receive very little exposure above background.

Facius, H. Nuclear Power Stations and the Environment. (Kraftwerk Union A.G., Offenbach (German, F.R.)). (May 1977). (In German).

Nuclear power stations are being given particular attention by the public and in many cases they are presented as the energy generator which threatens special danger to the environment. Although there is no scientific controversy over the fact that the pollution of the environment caused by coal- and oil-fired power stations is far greater than that from nuclear power stations, the negative attitude may be due to the undetectable danger produced by radioactive radiation. What is the actual position. The author attempts, on the basis of available operational reports and neutral authorities, to get to the bottom of the questions of environmental pollution by nuclear power stations.

Faust, R. Power Plant Operation and Climate. (Deutscher Wetterdienst-Wetteramt, Essen). 1975. (In German).

A definition of climate is given, and its elements and characteristics are described. Waste heat and lost water, which are discharged into waters and atmosphere by means of various cooling systems, cause meteorological changes which are discussed with regard to their qualitative and quantitative influence on the environmental climate. Reference is also made to the numerical treatment of diffusion factors. An outlook is given on the possible long-time effects of industrial civilization, of which reactor operation is an important part, on the environmental climate.

Fishbein, L. Consequences of New Energy Patterns. Final Report 1970-76. (New York Univ., N.Y. (USA). Task Force for Research Planning in Environmental Health Sciences (2nd)). Dec 1976. p. 39.

The major objective of this overview is to briefly highlight the potential problem areas and research needs as a consequence of new energy patterns impacting on the nation's water sources and quality. In terms of trends in energy demand, it is important to stress the dramatically increased use of electricity. Studies on coal, oil, nuclear energy, geothermal energy and oil shale are covered. (Portions of this document are not fully legible).

Fliermans, C.B.; R.W. Gorden, T.C. Hazen, G.W. Esch. Distribution of Aeromonas Hydrophila in a South Carolina Cooling Reservoir. (Du Pont de Nemours (E.I.) and Co., Aiken, S.C. (USA). Savannah River Lab.; Wake Forest Univ., Winston-Salem, N.C. (USA). Dept. of Biology). 1977.

Par Pond is a thermally enriched monomictic southeastern lake which receives heated effluent from a production nuclear reactor. Fish populations in the lake have lesions of epizooty from which *Aeromonas* spp. are readily isolated. Distribution and population densities of *Aeromonas* in the water column were measured along an oxygen and temperature gradient. Greater population densities of *Aeromonas* occurred below the oxygen chemocline when the lake was stratified. Survival of *A. hydrophila* under in situ conditions in both epilimnetic and hypolimnetic waters was determined using polycarbonate membrane diffusion chambers, during two separate reactor operating conditions. Survival levels of pure cultures of *A. hydrophila* corresponded to the distribution patterns of the naturally occurring *Aeromonas*-like populations. The greater survival of *A. hydrophila* below the chemocline when the reactor was in full operation suggests that the fish populations may be exposed to *Aeromonas* for a longer period of time than when the reactor is not operating.

Flowers, B. Nuclear Power and Public Policy. (Apr 1977).

Some of the thinking behind the Sixth Report of the Royal Commission on Environmental Pollution 'Nuclear Power and the Environment', is explained by the then Chairman of the Commission, who elucidates on various sections of the report and replies to some of the criticisms which followed its publication. Attention is drawn to other recent publications concerned with the environmental risks and problems of nuclear power, particularly the report of the Fox Commission on the Ranger Uranium Environmental Inquiry, in Australia, which reached similar conclusions to those of the Royal Commission. The Fox Commission studied the problems of safeguards and proliferation in much greater detail and its opinions are quoted. In conclusion, some personal recommendations are made as to the steps which the British Government should take, in regard to safeguards, waste management and designing against sabotage and natural disasters. Dependence upon nuclear power should be reduced. Commercial fast reactor development should proceed without undue haste and on a European basis.

Ford, A.; H.W. Lorber. Methodology for the Analysis of the Impacts of Electric Power Production in the West: A Summary Report. (Los Alamos Scientific Lab., N.Mex. (USA)). 1977. p. 9.

The project objective is to design a computer-based tool to help decision makers analyze some of the crucial environmental, social, and economic impacts--particularly the following impacts which involve conditions that are unique to the West: the boom town impacts that result from the construction and operation of power plants near small, isolated towns in the sparsely populated West; and the reduction in visibility caused by the fossil fuel emissions from power plants operating in the pristine West. Additional impacts that have been addressed include public health effects from fossil fuel pollutants, occupational health and safety, and the risk of accidental release of radioactive pollutants from nuclear power plants. The scale along which most of these varied impacts are compared is dollars. As an example, the report includes a demonstration showing how the methodologies can be used to calculate impacts associated with the 1985 expansion plan of the electric utilities belonging to the Western Systems Coordinating Council (WSCC). The paper concludes with a discussion of the usefulness of the results and a description of the work to be undertaken later in the project.

Foster, R.F. ANS Program for Standards to Control Environmental Impacts. (Battelle Northwest Labs., Richland, WA); Voileque, P.G.; Waters, B.F. (Nov 1976).

Franzen, L.F. Importance of Hypothetic Accidents in Nuclear Power Stations. (Institut fuer Reaktorsicherheit der Technischen Ueberwachungs-Vereine e.V., Koeln (Germany, F.R.)). Jan 1975. p. 38. (In German).

Only the recently available extensive reactor safety studies, which give a comprehensive survey on the probability and extent of failures, give a more realistic picture of the hazards connected with nuclear power. These hazards are certainly smaller than other commonly accepted technical risks. Even natural hazards are often greater.

Gibson, C.I.; K.H. Abel, S.W. Ahlstrom, E.A. Crecelius, R.L. Schmidt, T.O. Thatcher, R.E. Wildung. Biological Availability of Energy Related Effluent Material in the Coastal Ecosystem. May 1977.

In order to make the predictions necessary to forecast the ecological consequences of an energy-related technology, there must be an understanding of the biogeochemical processes involved in the natural system, the manner in which an energy technology affects these processes and how, in turn, this affects the ecosystem as a whole. Direct biological effects such as lethality, behavioral changes, and physiological changes, are being studied under the program previously discussed. The biological availability and impact studies are investigating: the chemical, physical, and

biological processes that occur in the natural marine ecosystem; how energy effluents affect these processes; and the factors involved in regulating the bioavailability of effluent material. This past year's effort has centered on defining the quantities and forms of metals and radioisotopes in nuclear power plant effluent streams, the chemical forms present in bioassay systems, the chemical and microbial processes controlling the forms of metals available from the sediments, and the uptake and control of copper in shrimp. In addition, several sites in Sequim Bay have been monitored for potential use in field verification studies.

Gibson, C.I.; C.W. Apts, T.O. Thatcher, J.S. Young. Power Plant Heat and Chemical Effluent Effects on Selected Marine and Estuarine Communities. May 1977.

Results are reported from research on the effects of energy-related effluents on marine coastal organisms and communities. The goal of this research on the effects of energy effluents on marine coastal organisms and communities is to: assess the immediate impact of an energy technology; make predictions about the long-term impacts and ecological consequences; and, provide background on the biological processes needed to understand biological availability and fate of energy effluent materials. The information resulting from this research is needed for the design and siting of existing energy technologies, i.e., nuclear and fossil fuel steam electric generation stations, gas liquifaction plants, and for new technology such as the Ocean Thermal Energy Conversion concept. Research has been continued on the effects of temperature primarily as a co-factor with other effluent materials, copper and biocides. The effects of these materials have been studied alone and in combination for periods of time ranging from 96 hrs to 6 months.

Gotchy, R.L. Comparison of Long-Term Environmental Impacts: More Questions Than Answers. (Nuclear Regulatory Commission, Washington DC). (Jun 1978).

Grace, J.B. Distribution and Abundance of Submerged Aquatic Macrophytes In a Reactor Cooling Reservoir. (Du Pont de Nemours (E.I.) and Co., Aiken, S.C. (USA). Savannah River Lab.). Aug 1977. p. 153.

Measurements of ash-free dry weight were used to characterize the effects of a heated effluent on submerged macrophytes in a reactor cooling reservoir. The species which were most abundant during the summers of 1974 and 1975 were *Myriophyllum spicatum* L. and *Eleocharis acicularis* (L.) R. and S. Examination of the vertical distribution of the shoot biomass of *Myriophyllum* revealed that plants in heated areas grew closer to the water surface than plants in unheated areas. The biomass of the second most abundant species, *Eleocharis acicularis*, was less at 0.5 m depths in heated areas (more than 5C° warmer than unheated areas). Species diversity was greater at heated locations because of a greater equitability (i.e. evenness of distribution of biomass) among species.

Gray, R.H.; J.M. Haynes, J.C. Montgomery, R.G. Genoway, S.A. Barraclough, D.R. Anderson, T.O. Thatcher, R.M. Bean, T.L. Page. Effects of Water Quality Alterations on Fish Behavior. May 1977.

Objectives of this project are to study behavioral patterns of ecologically or economically valuable fish. Information on sensory--avoidance behavior, or preferential foraging habits, if definitively established by systematic observation can be constructively used in both outfall and water intake design to ameliorate potentially noxious disturbances caused by these structures. The work is applicable to both nuclear and fossil fuel-fired steam electric plants. The instantaneous response of juvenile chinook salmon encountering a simulated river thermal plume interface was also evaluated in a model raceway. Tests indicate that juvenile chinook salmon perceive and avoid discharge temperatures greater than 9 to 11°C above ambient, regardless of acclimation temperature. Chlorine is a major chemical compound to reduce biofouling in steam electric power plants. Chlorination of large volumes of cooling waters poses the problem of the formation of chlorination by-products discharged to natural water systems. Long-term bioassays, both fresh and salt water, are underway with indepth analytical chemistry to determine the magnitude of the chlorination by-product problem.

Guilhamon, J. Nuclear Power Stations and the Environment. p. 9.

The expanding need for sources of electric power in France is discussed and the safety of nuclear power plants is emphasized.

Gustavsson, I. Concentration of Heavy Metals in the Receiving Waters Off the Nuclear Power Plants of Sweden. (Statens Naturvaardsverk, Stockholm (Sweden)). Sep 1976. p. 16.

The concentrations of heavy metals in the water off the nuclear power plants in Sweden in 1975 were normal. Occasional peaks were recorded, but in no case did they reach alarming heights.

Halusi-Kun, G.J. Water Use Implications for Nuclear Power Stations in the United States of America. (Columbia Univ. New York). (1975).

The problems in selecting reactor sites are discussed in terms of population density, coolant water demand, thermal pollution and engineered safeguard measures during construction and operation.

Hamilton, L.D.; S.C. Morris, C.E. Calef, E. Kaplan, D.F. Shreeve, A.W. Reisman. Perspective on the Energy Future of the Northeast: Health and Environmental Impacts of Alternative Energy Futures for the Northeast. (Brookhaven National Lab., Upton, N.Y. (USA)). 1976. p. 25.

Attention was focused on five air pollutants sulfur oxides, nitrogen oxides, particulates, unburned hydrocarbons, and carbon monoxide. Emission coefficients were based on data in the BNL

Energy Model Data Base. Tables are presented to show emission factors for electricity generation, for industrial energy use, and for Transportation sector. Health effects of air pollution, health impacts of nuclear power plants, and environmental considerations are also discussed.

Handage, P. (Gesellschaft fuer Reaktorsicherheit (GRS), Koeln (Germany, F.R.). Abt. Strahlenschutz). (Mar 1977). (In German).

Supplying the proof before taking up operation, emission and emission monitoring during operation, performance and testing of the monitoring equipment.

Hansmann, K. Environmental Compatibility Examination in Nuclear Licensing. pp 93-99 of Fuenftes Deutches Atomrechts-Symposium. Referate und Diskussionsberichte, Lukes, R. (ed.) (Muenster Univ. (Germany, F.R.). Inst. fuer Arbeits- und Wirtschaftsrecht). Loeln, Germany, G.R.; Heymanns (1977). (In German)

The interpretation of the binding effect of section 7, subsection 2, figure 6 of the Atomic Energy Act for nonnuclear-specific environmental factors is declined, and for this reason a nuclear-specific reference is asked for.

Harrison, F.L. Chemical Effluents Surface Waters From Nuclear Power Plants. Quarterly Progress Report. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 31 Oct 1977. p. 15.

The objectives of this research project are three-fold: to obtain data on the behavior of potentially toxic substances introduced into surface waters from nuclear power plants; to determine the impact magnitude of these substances on representative and economically important aquatic species; and to develop models with which to predict the partitioning of these substances among the abiotic aquatic compartments. Results are reported from investigations of copper partitioning in seawater, evaluating the toxicity of copper in representative marine organisms, and development of a mathematical model to predict copper partitioning.

Harrison, F.L.; R.R. Emerson, D.W. Rice, Jr. Impact and Fate on Aquatic Environments of Copper From Nuclear Power Plants. (Univ. of California, Livermore). (Jun 1977).

Harrison, F.L. Quarterly Progress Report on Chemical Effluents in Surface Waters from Nuclear Power Plants. (California Univ., Livermore (USA). Lawrence Livermore Lab.). 28 Jul 1977. p. 14.

Results are reported from research project to obtain data on the behavior of potentially toxic substances introduced into surface waters from nuclear power plants, the impact magnitude of these substances on representative and economically important aquatic species, and the development of models with which to predict the partitioning of these substances among the abiotic aquatic compartments. Data are included from an investigation of copper

partitioning in freshwater and seawater, the toxicity of copper to representative marine organisms, and a mathematical model to predict copper partitioning.

Hendrickson, P.L.; C.L. McDonald, A.H. Schilling. Review of Decision Methodologies for Evaluating Regulatory Actions Affecting Public Health and Safety. (Battelle Pacific Northwest Labs., Richland, Wash, (USA)). Dec 1976. p. 112.

This report examines several aspects of the problems and choices facing the governmental decision maker who must take regulatory actions with multiple decision objectives and attributes. Particular attention is given to the problems facing the U.S. Nuclear Regulatory Commission (NRC) and to the decision attribute of chief concern to NRC, the protection of human health and safety, with emphasis on nuclear power plants. The study was undertaken to provide background information for NRC to use in refining its process of value/impact assessment of proposed regulatory actions. The principal conclusion is that approaches to rationally consider the value and impact of proposed regulatory actions are available. These approaches can potentially improve the decision-making process and enable the agency to better explain and defend its decisions. They also permit consistent examination of the impacts, effects of uncertainty and sensitivity to various assumptions of the alternatives being considered. Finally, these approaches can help to assure that affected parties are heard and that technical information is used appropriately and to the extent possible. The principal aspects of the regulatory decision problem covered in the report are: the legal setting for regulatory decisions which affect human health and safety, elements of the decision-making process, conceptual approaches to decision making, current approaches to decision making in several Federal agencies, and the determination of acceptable risk levels.

Hladky, E. Comparison of Environmental Effects of Conventional and Nuclear Power Plants. (Vyzkumny Ustav Energeticky, Jaslovske Bohunice (Czechoslovakia)). (May 1976). (In Czech).

The relations are defined permitting the comparison of the effects of conventional and nuclear power plants on the living environment on the basis of the amount of annually discharged emissions. The function of relative damage of the living environment (mainly of population) is determined from the maximum calculated values of emission concentrations.

Hoagland, K.E., L. Crockett, M. Rochester. Effects of Nuclear Power Plant Operations on Populations of Boring and Fouling Organisms. (Lehigh Univ., Stone Harbor, N.J. (USA). Wetlands Inst.). Mar 1978. p. 50.

The power plant was operating during the fall of 1977. The temperature elevation in Oyster Creek was between 3.5° and 6°C. Salinities in Oyster Creek and Forked River vary more than salinities in Barnegat Bay. *Teredo* spp. settle later into the fall than *Bankia gouldi*. Several *Teredos* settled in Oyster Creek in September and October. They also settled on Long Beach Island, but at no other stations. Comparison of hydrography with shipworm settlement patterns indicates that shipworm larvae are abundant in regions of rapidly moving water and require only very localized quiet areas for successful settlement. Shipworm settlement in Oyster Creek in the fall of 1976 was not great enough to affect the population structure significantly. Settlement in the fall of 1977 was detectable in November's population size structure. *Teredo* spp. dominate borer communities on Long Beach Island, while *Bankia* is more common along the inner side of Barnegat Bay. Shipworms continued to grow in the fall of 1977, even at stations outside the thermal plume. Shipworm damage in Oyster Creek and Forked River remains significant.

Hoerning, H. Reactors and Environment. (Jun 1976). (In German).

Statements are made on the following main points in the field of 'nuclear technology, nuclear reactors and environment' in order to elucidate the problems and to promote an object approach: 1) the paths of radiation with regard to individuals during normal operation and during incidents in nuclear power plants, 2) permissible radiation loads according to the Radiation Protection Ordinance and the real loads to be expected during normal operation and during incidents, 3) the natural and the man-made radiation load of the population, 4) dose-effect relation, 5) tritium emission within the fuel cycle, 6) the release of ⁸⁵Kr from nuclear power plants and reprocessing plants, 7) information on Pu and its dangers, 8) the storage of radioactive wastes and the safety of reactors against incidents within the plant itself and against external effects, 9) comparison between the impact on the environment of nuclear power plants and of power stations operated with coal and oil, and 10) waste heat of nuclear power plants.

Hoffman, F.O.; C.W. Miller, D.L. Shaeffer, C.T. Garten, Jr., R.W. Shor, J.T. Ensminger. Compilation of Documented Computer Codes Applicable to Environmental Assessment of Radioactivity Releases. (Oak Ridge National Lab., Tenn. (USA)). Apr 1977, p. 83.

The objective of this paper is to present a compilation of computer codes for the assessment of accidental or routine releases of radioactivity to the environment from nuclear power facilities. The capabilities of 83 computer codes in the areas of environmental transport and radiation dosimetry are summarized in tabular form.

This preliminary analysis clearly indicates that the initial efforts in assessment methodology development have concentrated on atmospheric dispersion, external dosimetry, and internal dosimetry via inhalation. The incorporation of terrestrial and aquatic food chain pathways has been a more recent development and reflects the current requirements of environmental legislation and the needs of regulatory agencies. The characteristics of the conceptual models employed by these codes are reviewed. The appendixes include abstracts of the codes and indexes by author, key words, publication description, and title.

Hoglund, B.M. Environmental Impact Statements: Their Preparation and Their Problems. (Environmental Tech. Assessment, Inc., Oak Brook, IL). pp 446-458 of In Environmental impact of nuclear power plants. Karam, R.A. (ed.) Elmsford, NY; Pergamon Press, Inc. (1976).

The discussion describes in general terms the process by which the AEC and their contractors develop Environmental Impact Statements and describes some of the problems they have encountered in the process. This is a very dynamic process which is still on the relatively steep part of the learning curve. Many of the initial problems have been solved, some new problems have been discovered, and greater insights and better techniques for analyzing environmental impacts are being developed. The author maintains that both the AEC and the utilities are turning out good environmental reports and impact statements and are setting the standards for the rest of the country in analyzing environmental impacts.

Jaworowski, Z. Population Hazards Associated With Fossil Fuel and Nuclear Power Production. (Centralne Lab. Ochrony Radiologicznej, Warsaw (Poland)). (1975). (In Polish).

The additional number of deaths has been estimated in the population neighbouring an atomic power station (1000 MWe) as compared with a coal power station of the same power output, caused by the dissipation of natural and artificial radionuclides, sulphur dioxide and dust into the atmosphere. The non-radiation hazard from a thermal power station was found to be about 6 orders of magnitude higher than the radiation hazard from a PWR-type atomic power station. The hazard due to radium-226 dissipated by power stations running on coal are several hundred times higher than that due to radioactive noble gases and iodine-131 dissipated by PWR-type atomic power stations.

Karam, R.A.; K.Z. Morgan. (eds.). Environmental Impact of Nuclear Power Plants. Proceedings of a Conference Held in Atlanta, Georgia, November 26--30, 1974. Elmsford, NY; Pergamon Press, Inc. (1976). p. 555.

Twenty-three papers are presented on topics including plant site selection; ecosystems and ecological effects; radioactive waste and thermal pollution; standards and guidelines in the preparation of environmental reports; cost-benefit analysis; and environmental impact studies of various power sources. Each paper has been separately abstracted and indexed.

Kastenber, W.E.; T.E. McKone, D. Okrent. Risk Assessment in the Absence of Complete Data. (California Univ., Los Angeles (USA). School of Engineering and Applied Science). Jul 1976. p. 50.

A major problem in assessing risks in advanced systems is that (1) all of the potential consequences are not known nor anticipated, and (2) even when risks are anticipated there is uncertainty in the data. Several mathematical risk assessment theories are summarized, and their deficiencies in the absence of complete data are discussed. The mathematical basis of risk assessment is considered, and the basic problems of moving from a discrete to a continuous consequence-frequency distribution are discussed. The application of these concepts to waste disposal and storage of high level radioactive waste, risk to ground populations due to airline crashes, and nuclear power plant risks are reviewed and discussed.

Kaye, S.V. Analysis and Assessments. Nov 1977.

Progress is reported in the areas of development and evaluation of methods and project applications. Some research projects are as follows: data base for dosimetry of radionuclides in the environment; reduction in population doses from atmospheric releases of radionuclides; computer code for calculating concentrations of pollutants emitted from dispersed sources; dose to man as a result of tritium releases from nuclear facilities; environmental assessment of advanced LMFBR fuels; radiological assessment of burial of high-level solid wastes; nuclear fuel cycle ALARA studies; radiological assessments for environmental impacts statements; survey of ecological aspects of risks associated with nuclear power; and consumer products containing radionuclides.

Kellermann, O. Environmental Impact Due to Nuclear Power Plants. An Attempt to Determine the Risk Factor. (Institut fuer Reaktorsicherheit der Technischen Ueberwachungs-Vereine e.V., Koeln (F.R. German)); Balfanz, H.P. (Institute fuer Reaktorsicherheit der Technischen Ueberwachungs-Vereine e.V., Koeln (F.R. German). (Dec 1975). (In German).

The environmental impact due to nuclear power plants is smaller than that due to fossil-fired power plants. The risks of the nuclear power plant operation are determined by the quantity and the probability of the release of radioactive materials. According to the value, the risks of normal operation can be compared to the accident risks. An attempt should be made to effectively reduce the remaining risk at unfavourable sites with the emphasis on accidents with larger effects than design basis accidents.

Klingebiel, U. Environmental Protection and Nuclear Power Plants.
VEB Kombinat Kraftwerksanlagenbau, Berlin (German Democratic Republic)). (1976). (In German).

Some principles of environmental protection in constructing and operating nuclear power plants are described and explained using the The insberg and 'Bruno Leuschner' Greifswald nuclear power stations as examples. Methods of processing and storage of liquid and gaseous wastes from nuclear power plants as well as problems of nuclear safety are considered. Furthermore, the measures of radiation protection surveillance inside and outside the plant, licensing, and inspection are discussed. The effects of nuclear power plants and conventional power plants on the environment are compared.

Kroodsma, R.L.; R.B. Craig, S.G. Hildebrand. Ecological Analyses and Applications. Mar 1978.

Progress is reported on the following: assessment of nuclear power plants; ecological analysis of uranium mining, milling, and fuel fabrication, environmental impacts statements concerning uranium enrichment facilities; site evaluations for storage of radioactive wastes; ecological analysis of geothermal energy development; enhanced oil recovery; environmental monitoring plant for modular integrated utility systems; and fossil energy environmental project.

Lied, F. Nuclear Power and our Environment. (28 Jan 1977). (In Norwegian).

The main points of the Sixth Report of the Royal Commission on Environmental Protection are presented and briefly discussed. The author suspects that disagreements within the Commission have led to the use of formulations with deliberate subtleties and ambiguities, and would have preferred open statements of disagreements. The alternative energy strategy proposed by the Commission is contrasted with the official strategy, and the author finds this a realistic statement of the available choices. That fossil-fueled power is proposed phased out for environmental reasons by the Commission is recommended to the attention of the Swedish Prime Minister and other environmental quarters. It is also pointed out that this is in accordance with the environmental authorities' policy in Sweden. Finally the author quoted the comments in 'Nature' (v. 264, p. 494) and underlines the need for establishing objective criteria by which safety may be judged.

Lietake, M.H. Validation of the Kinetic Model for Predicting the Composition of Chlorinated Water Discharged From Power Plant Cooling Systems. (Oak Ridge National Lab., Tenn. (USA)). 31 Oct 1977. p. 18.

The purpose of this report is to present a validation of a previously described kinetic model which was developed to predict the composition of chlorinated fresh water discharged from power plant cooling systems. The model was programmed in two versions: as a stand-alone program and as a part of a unified transport model developed from consistent mathematical models to simulate the dispersion of heated water and radioisotopic and chemical effluents from power plant discharges. The results of testing the model using analytical data taken during operation of the once-through cooling system of the Quad Cities Nuclear Station are described. Calculations are also presented on the Three Mile Island Nuclear Station which uses cooling towers.

Maier, G. Energy Supply and Environmental Protection as Conflicting Targets. (Mar 1976). (In German).

The conflict between sufficient energy supply and efficient environmental protection is didactically analysed as a complex of topics for the political education. Education principles and sequences basing on opinions of supporters and opponents of nuclear energy are shown. Aims of education are briefly shown with the examples of the energy supply of the FRG and the energy problems of Europe.

Mattrice, J.S. Power-Plant Discharges: Toward More Reasonable Effluent Limits on Chlorine. (Oak Ridge National Lab., TN). (1977).

A method is presented for restricting chlorine in power-plant effluents to environmentally safe levels. Development of this method was stimulated by the controversy between electric utilities and regulatory agencies over the justification of the present universally applied limits. The scientific literature conclusively demonstrates the effects of physical, chemical, and biotic factors on chlorine toxicity. The method proposed includes these factors, to the extent currently possible, to set limits based on site-specific aquatic conditions and plant design and operation specifications. In these effluent limits, the organisms considered are those which are entrained into the plume or which maintain themselves within the plume during chlorination. In each instance the time course of exposure concentration is divided into small time intervals. Weighted mean concentrations for successively larger time intervals following initial exposure are then calculated. Exposures resulting from releases at various levels are compared either graphically or mathematically with acute and chronic mortality thresholds to find the highest discharge concentration that does not cause mortality. The thresholds are derived from existing toxicity data and are different for marine and freshwater organisms.

This method is based on the latest literature available and can incorporate further data concerning chemistry, toxicity, and behavior as they become available. The method also is amenable to coupling with models of chemical dispersion and population dynamics to permit more complete analysis. This approach serves to permit use of chlorine for biofouling control at power plants, while ensuring that this use will not be inimical to the environment.

Maurer, K.M. Parametric Utility Comparison of Coal and Nuclear Electricity Generation. (California Univ., Los Angeles (USA). Dept. of Chemical, Nuclear, and Thermal Engineering). Feb 1977. p. 72.

The advantages and limitations of an explicit quantitative model for decision making are discussed. Several different quantitative models are presented, noting that the use of an expected utility maximization decision rule allows both the direct corporation of multidimensional descriptions of the possible outcomes, and considerations of risk-averse behavior. A broad class of utility functions, characterized by linear risk tolerance, was considered and extended to a multidimensional form. Choosing a multivariate risk neutral extension, using constant absolute risk aversion utility functions for monetary effects and for increased mortality, the author indicated how the parameters of this utility function can be selected to represent the decision maker's preferences, and suggest a reasonable range of values for the parameters. After describing an illustrative set of data on the risks inherent in coal burning and nuclear electricity generation facilities, the author used the chosen utility model to compare the overall risks associated with each technology, observing the effect of variations in the utility parameters and in the risk distributions on the implied preferences.

McBride, J.P.; R.E. Moore, J.P. Witherspoon, R.E. Blanco. Radiological Impact of Airborne Effluents of Coal-Fired and Nuclear Power Plants. (Oak Ridge National Lab., Tenn. (USA)). Jun 1977. p. 43.

Radiological impact of naturally occurring radionuclides in airborne effluents of a model coal-fired steam plant is evaluated assuming a release to the atmosphere of 1 percent of the ash in the coal burned and compared with the impact of radioactive materials in the airborne effluents of model light-water reactors. The principal exposure pathway for radioactive materials released from both types of plants is ingestion of contaminated foodstuffs. For nuclear plants immersion in the airborne effluents is also a significant factor in the dose commitment. Assuming that the coal burned contains 1 ppm uranium and 2 ppm thorium together with their decay products and using the same impact analysis methods used in evaluating nuclear facilities, the maximum individual dose commitments from the coal plant for the whole body and most organs (except the thyroid) are shown to be greater than those from a pressurized-water reactor (PWR) and, with the exception of the bone and kidney doses, less than those from a boiling-water reactor

(BWR). With the exception of the bone dose, the maximum individual dose commitments from the coal plant are less than the numerical design guideline limits listed for light-water reactors (LWRs). Population dose commitments from the coal plant are higher than those from either nuclear plant.

McCaughran, D.A. Quality of Inferences Concerning the Effects of Nuclear Power Plants on the Environment. (Univ. of Washington, Seattle). pp 229-242 of Proceedings of the Conference On Assessing the Effects of Power-Plant-Induced Mortality On Fish Populations. Van Winkle, W. (ed.). Elmsford, NY; Pargamon Press Inc. (1977).

The analysis of variance is the most common statistical procedure applied to nuclear power plant monitoring data at the present time. Under the assumption that it is appropriate, minimum detectable difference is defined and its relationship with the power of the statistical test is computed. The relationship between station number, replicate number, variance, and minimum detectable difference with power = 0.90 and $\alpha = 0.10$ for phytoplankton, zooplankton, smelt, and alewives at the Zion Nuclear Power Plant are given.

McClusky, J.P. Some Frustrations of Environmental Red Tape. (Commonwealth Edison Co., Chicago). (Jun 1978).

McKenzie, D.H.; L.D. Kannberg, K.L. Gore, E.M. Arnold, D.G. Watson. Design and Analysis of Aquatic Monitoring Programs at Nuclear Power Plants. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Nov 1977. p. 139.

This report addresses some of the problems of designing, conducting, and analyzing aquatic environmental monitoring programs for impact assessment of nuclear power plants. The concepts discussed are applicable to monitoring the effects of chemical, radioactive, or thermal effluents. The concept of control and treatment station pairs is the fundamental basis for the experimental method proposed. This concept is based on the hypothesis that the relationship between the two stations forming the pair can be estimated from the preoperational period and that this relationship holds during the operational period. Any changes observed in this relationship during the operational period are assumed to be the result of the power plant impacts. Thus, it is important that station pairs are selected so it can be assumed that they respond to natural environmental changes in a manner that maintains that relationship. The major problem in establishing the station pairs will be the location of the control station. The universal heterogeneity in the environment will prevent the establishment of identical station pairs. The requirement that the control station remain unaffected by the operation of the power plant dictates a spacial separation with its associated differences in habitat. Thus, selection of the control station will be based upon balancing the following two criteria: (1) far enough away from the plant site to be beyond the plant influence, and (2) close enough to the treatment station that the biological communities will respond to natural environmental changes consistently in the same manner.

Medrano, G.; J. Polimon. Implementation of Environmental Programs for Surveillance of Nuclear Installations. (International de Ingenieria y Estudios Tecnicos, Madrid). (1977).

Metke, E.; S. Novak. Development of Nuclear Power Plants in Czechoslovakia and Their Effect on the Living Environment. (Vyskumny Ustav Energeticky, Bratislava (Czechoslovakia)). (Jan 1977). (In Slovak).

The envisaged contribution of nuclear power plants to the installed capacity in Czechoslovakia and other industrially advanced countries till 1990 is compared. In Czechoslovakia, the application of reactors of the WWR 440 and WWR 1000 types are envisaged. Their basic characteristics are given and compared to corresponding reactor types operating abroad. The effect is discussed of nuclear power plants on the environment as against conventional power plants. A survey is made of the average annual emission of radioactive gases, aerosols and iodine isotopes related to certain nuclear power plants in the world. The evaluation of radiation load in the neighbourhood of conventional power plants due to ^{226}Ra and ^{228}Ra shows that in conventional power plants of a capacity of 1000 MW the radiation load is about thirty times higher than that in the same capacity WWR nuclear power plants and lower by several orders than in boiling water reactor power plants. According to forecasts till 1990, for the projected nuclear power capacity the average population load in Czechoslovakia will be more than 400 times less than for the same capacity were it covered by conventional power plants.

Morgan, J.J.; W. Bach, E. Eriksson. Source Functions: Fossil Fuel Combustion Products, Radionuclides, Trace Metals, and Heat. Group Report. pp 291-311 of In Global chemical cycles and their alterations by man. Stumm, W. (ed.). Berlin; Abakon Verlagsgesellschaft (1977).

Global chemical cycles involve a variety of sources, sinks, reservoirs, and fluxes of the chemical elements and their compounds. For global cycles, in principle, all natural and man-influenced sources and sinks for chemical substances and energy are of potential significance. Interactions of chemical and energy source functions in affecting global environment may be strong. Source functions of special interest are those which characterize man's alteration of global cycles, for example fluxes of carbon dioxide, radionuclides, fixed nitrogen, heat, toxic substances such as trace metals, and synthetic organics. Topics discussed include some aspects of the CO_2 problem, including CO_2 source functions and future CO_2 burdens in the atmosphere; climatic consequences; possible errors in measuring fossil fuel consumption; radionuclides from the nuclear fuel cycle (release, global distributions, and population exposure); global mobilization of metals; the solar constant; the albedo; and halocarbons.

Moore, R.E. AIRDOS-II Computer Code for Estimating Radiation Dose to Man From Airborne Radionuclides in Areas Surrounding Nuclear Facilities. (Oak Ridge National Lab., Tenn. (USA)). Apr 1977. p. 159.

The AIRDOS-II computer code estimates individual and population doses resulting from the simultaneous atmospheric release of as many as 36 radionuclides from a nuclear facility. This report describes the meteorological and environmental models used in the code, their computer implementation, and the applicability of the code to assessments of radiological impact. Atmospheric dispersion and surface deposition of released radionuclides are estimated as a function of direction and distance from a nuclear power plant or fuel-cycle facility, and doses to man through inhalation, air immersion, exposure to contaminated ground, food ingestion, and water immersion are estimated in the surrounding area. Annual doses are estimated for total body, GI tract, bone, thyroid, lungs, muscle, kidneys, liver, spleen, testes, and ovaries. Either the annual population doses (man-rems/year) or the highest annual individual doses in the assessment area (rems/year), whichever are applicable, are summarized in output tables in several ways--by nuclides, modes of exposure, and organs. The location of the highest individual doses for each reference organ estimated for the area is specified in the output data.

Morris, S.C. Comparative Effects of Coal and Nuclear Fuel on Mortality. (Brookhaven National Lab., Upton, N.Y. (USA)). Aug 1977. p. 7.

A key part of risk assessment is estimation of population exposure. This might ideally be a compilation of the number and characteristics of people exposed to given kinds, levels, and combinations of risk. The compilation ideally would be sufficiently disaggregated to allow calculation of the joint frequency of various combinations of risk to which a single population might be exposed. The number of people exposed at each level of risk is important since the true health damage function (or dose-response function) is likely to be nonlinear. At this point in our models, we are not considering synergisms. We attempt to define the population exposed, and the degree of exposure, but treat the population at each exposure level as a single class. We also use linear damage functions. While these probably do not adequately represent the true effects over a wide range of exposure, we believe they are adequate to predict the effect of small changes of exposure within the general range of previous observation. Moreover, in our air pollution models we are generally allocating part of the total effect of air pollution to a specific source. A linear model seems completely appropriate for this use. We measure mortality in excess or attributable deaths per power-plant year. Excess deaths is a convenient way to express changes in mortality rates.

Moscatti, A.F. Jr. Environmental Issues in the Siting, Construction, and Operation of New Coal-Fired and Nuclear Power Plants. Los Angeles; Univ. of California (1975). p. 197.

A discussion is presented of some of the major interfaces between efforts toward environmental preservation and the expansion of the nation's power supply. Ways in which environmental goals may be attained within the framework of a comprehensive energy policy are also discussed. The study is limited to an examination of the environmental issues encountered in the siting, construction and operation of new coal-fired and nuclear power stations; no attempt is made to evaluate environmental aspects of such related activities as fuel mining, processing and recycling. Recommendations made concerning the integration of environmental concerns into the regulatory framework include suggestions for streamlining the environmental review process. The report includes a summary of the internship served with Bechtel Power Corporation under the auspices of the Environmental Science and Engineering Program of UCLA.

Murarka, I.P.; D.J. Bodeau. Software Documentation and User's Manual for Fish-Impingement Sampling Design and Estimation Method Computer Programs. (Argonne National Lab., Ill. (USA)). Nov 1977. p. 92.

This report contains a description of three computer programs that implement the theory of sampling designs and the methods for estimating fish-impingement at the cooling-water intakes of nuclear power plants as described in companion report ANL/ES-60. Complete FORTRAN listings of these programs, named SAMPLE, ESTIMA, and SIZECO, are given and augmented with examples of how they are used.

Murarka, I.P.; D.J. Bodeau, W.K. Derickson. Validation and Software Documentation of the ANL Fish-Impingement Model. (Argonne National Lab., Ill. (USA)). Apr 1978. p. 126.

This report contains the results of a validation test of the ANL Fish Impingement Model. By the use of 1974 fish-impingement and environmental data from the Zion Nuclear Power Station, it is shown that the modified and expanded mathematical model yields reasonably good results in calculations of daily fish-impingement losses at the cooling water intakes. Comparisons confirmed that the fish-impingement process depends primarily on the abundance of fish in the vicinity of a cooling water intake, whereas the probability function gives the susceptibility to impingement provided that fish are present in the intensity region. In view of the limited amount of information available with regard to the various environmental and fish-abundance factors, it appears that the present form of the model is adequate and that efforts to refine the model further are not warranted.

Nagel, D.; D. Papadopoulos. WOLGA 1, a FORTRAN IV Program for Calculation of the γ -dose Rate from Radioactive Effluent Air Released By One or Several Continuously Emitting Sources. (Kernforschungszentrum Karlsruhe. (Germany F.R.)) Oct 1975. p. 22.

The computer program Wolga 1 serves for the calculation of the gamma dose rate in the surroundings of one or more emitters which emit gamma-active waste gases continuously. Frequently distributions in the directions of expansion, the wind velocities and the expansion categories must be available. The program is used in the calculation of the environment because of the gamma-active emissions from the reactors at the Karlsruhe Nuclear Research Center (KRZK), among other things.

Nero, A.V.; M.S. Quinby-Hunt. Health and Safety Impacts of Nuclear, Geothermal, and Fossil-Fuel Electric Generation in California. Volume 9. Methodologies for Review of the Health and Safety Aspects of Proposed Nuclear, Geothermal, and Fossil-Fuel Sites and Facilities. (California Univ., Berkeley (USA). Lawrence Berkeley Lab.). Jan 1977. p. 162.

This report sets forth methodologies for review of the health and safety aspects of proposed nuclear, geothermal, and fossil-fuel sites and facilities for electric power generation. The review is divided into a Notice of Intention process and an Application for Certification process, in accordance with the structure to be used by the California Energy Resources Conservation and Development Commission, the first emphasizing site-specific considerations, the second examining the detailed facility design as well. The Notice of Intention review is divided into three possible stages: an examination of emissions and site characteristics, a basic impact analysis, and an assessment of public impacts. The Application for Certification review is divided into five possible stages: a review of the Notice of Intention treatment, review of the emission control equipment, review of the safety design, review of the general facility design, and an overall assessment of site and facility acceptability.

Partridge, J.E.; J.A. Broadway, C.R. Phillips, S.T. Windham, C.B. Nelson. Air Pathway Exposure Model Validation Study at the Monticello Nuclear Generating Plant. (Environmental Protection Agency, Washington, D.C. (USA)). Sep 1976. p. 27.

The results of a study designed to improve the methodology for estimating the population exposures resulting from nuclear power plant gaseous effluents are given. The primary objective of this study was to validate a mathematical model (AIREM) for estimating radiation exposures due to atmospheric radioactive releases. This validation was accomplished by comparing the model predictions with actual field measurements made using pressurized ionization chambers

and thermoluminescent dosimeters. Use of this model for predicting external exposures was shown to be quite acceptable for most applications. The usefulness of pressurized ionization chambers for making low-level exposure measurements was also demonstrated by this study.

Patrick, C.H.; A.S. Loeb1, F.L. Miller, P.N. Ritchey, Jr. Public Health and Demographic Statistics. Oct 1976.

The purpose of this program is to assess the methodology and available data sources appropriate for use in analytical studies and environmental impact statements concerning the health effects of nuclear power plants. The techniques developed should be applicable as well to evaluation of the known risks of high levels of radiation exposure and of conflicting evidence on low-level effects, such as those associated with the normal operations of nuclear power plants. To accomplish this purpose, a two-pronged approach has been developed. The first involves a determination of the public health and demographic data sources of local, state, and federal origin that are available for use in analyses of health effects and environmental impact statements. The second part involves assessment of the methods used by epidemiologists, biostatisticians, and other scientists as found in the literature on health effects. This two-pronged approach provides a means of assessing the strength and shortcomings of studies of the impact of nuclear facilities on the health of the general population in a given locality.

Rhodes, D.A.; P.F. Rad. Planning, Design, and Construction of Nuclear Power Plants: An Overview. Final Report. (Clemson Univ., S.C. (USA). Dept. of Civil Engineering). Dec 1977. p. 398.

Chapters are included on generation system descriptions and alternative energy sources; load forecasting and growth projections; utility studies, program development, and analytical models; organizational alternatives and contract arrangements; project control in the design and construction phase; site management activities; construction activities; and startup and testing.

Rosen, L.C. Review of Air Quality Modeling Techniques. Volume 8. (California Univ., Berkeley (USA). Lawrence Berkeley Lab.). Jan 1977. p. 47.

Air transport and diffusion models which are applicable to the assessment of the environmental effects of nuclear, geothermal, and fossil-fuel electric generation are reviewed. The general classification of models and model inputs are discussed. A detailed examination of the statistical, Gaussian plume, Gaussian puff, one-box and species-conservation-of-mass models is given. Representative models are discussed with attention given to the assumptions, input data requirement, advantages, disadvantages and applicability of each.

Saglio, J.F. Siting of Nuclear Power Stations and Environment. (Ministere de la Qualite de la Vie, 75 - Paris (France)). (Mar 1976). (In French).

A comparison is made between importance and type of harmful effects involved by traditional and nuclear stations. Consequences on different aspects of environment are successively examined: atmosphere, water, sites and landscapes.

Samworth, R.B. Power Plant Impact on Chemical Quality of Surface and Groundwaters. (Nuclear Regulatory Commission, Washington, DC). (Jun 1977).

Sather, H.N. Statistical Models for Competing Risk Analysis. (California Univ., Los Angeles (USA). Dept. of Energy and Kinetics). Aug 1976. p. 70.

Research results on three new models for potential applications in competing risks problems. One section covers the basic statistical relationships underlying the subsequent competing risks model development. Another discusses the problem of comparing cause-specific risk structure by competing risks theory in two homogeneous populations, P1 and P2. Weibull models which allow more generality than the Berkson and Elveback models are studied for the effect of time on the hazard function. The use of concomitant information for modeling single-risk survival is extended to the multiple failure mode domain of competing risks. The model used to illustrate the use of this methodology is a life table model which has constant hazards within pre-designated intervals of the time scale. Two parametric models for bivariate dependent competing risks, which provide interesting alternatives, are proposed and examined.

Schikarski, W. Nuclear Power Plants and the Environment. (1975). (In German).

Until 1985, a period for which the energy programme of the Federal government was set up, the effects the energy transformation and consumption in the FRG has on the environment are foreseeable and on the average they can be prognosticated. The threat to the environment from polluting agents emitted by single nuclear power plants is very small in comparison with the natural radiation exposure and with the radiation exposure from other energy carriers. The problem of waste heat will not be a limiting factor for energy technology within the next few years if an optimal application of the known recoling techniques for power stations ('Kuehlregie') materializes.

Schwille, F. Are Nuclear Power Plants a Danger to the Drinking Water Supply. (Zentralstelle fuer Atomkernenergie-Dokumentation (ZAED), Eggenstein-Leopoldshafen (Germany, F.R.)). 1974. p. 6. (In German).

As a rule, the nuclear reactors offer, due to their technical design, a complete protection of the ground water against radio-nuclide contamination. Due to the manifold utilization of surface waters, a strict limitation and monitoring of the introduction of radioactive waste waters of all kinds is indispensable. The heating of the surface waters by introduced cooling water still remains the only problem in the procurement of water. It arises, however, with all thermal power plants in the same manner and should therefore be discussed separately from nuclear power plants.

Scott, F.M.; K.V. Mayenkar. Pollution-Abatement Regulations for Nuclear Power Stations and Their Economic Impact. (Harza Engineering Co., Chicago). (1977).

The United States EPA, on October 8, 1974, published the final effluent guidelines and standards for discharges from steam electric generating plants. This paper contains a discussion of the BPCTCA and BATEA limitations for thermal and chemical effluent discharges from a nuclear steam electric power generating station and a review of the process technology available for pollution abatement. Both existing technology and technology currently under development are reviewed.

Seifritz, W. Role of Nuclear Energy in the More Efficient Exploitation of Fossil Fuel Resources. (Swiss Federal Inst. for Reactor Research, Wuerenlingen). (1978).

The energy theory of value, being a valuable addition to the debate on the rational exploitation of man's energy reserves, is applied in order to clarify the presently confused energy input/output relations for nuclear and solar systems as they interact with fossil fuel. It is shown on the basis of purely energetics considerations that the nuclear route--at present and in future--is a very efficient way to stretch out and finally to substitute for the limited fossil fuel resources. This is particularly true if one considers the transitory phase where the substituting process has to exhibit a rapid exponential growth rate. The energetical effectiveness of the production of a synthetic fuel, for example, hydrogen by water splitting processes, is addressed at the end and serves to give an idea how effectively the energy available in fossil fuels can be amplified by virtue of the coupling of nuclear energy into the process.

Sivintsev, Yu. V.; E.N. Teverovskii. Comparison of the Effects of Nuclear Power Plants and Thermal Power Plants on the Environment. Review. (Oct 1976). (In Russian).

A comparison of ecological effects produced by a thermal power station (TPS) and a nuclear power plant (NPP) of similar electric capacity has been made. The ecological advantages of NPP over TPS are revealed in analysis of aerosol and gas blow-out and its danger for the environment. From the above data it follows that TPS as compared with NPP of similar electric capacity produces a 100 and 1000 fold higher air pollution effect than the latter. The dose of TPS radiation effect is minimum 500 times higher than that of NPP at normal operation. Large-scale construction of NPP is one of the most perfect means of atmosphere protection against harmful industrial discharges.

Smith, D. More Black Death Than Black Gold. (Feb 1977).

Statistics given in the U.S. Council on Economic Priorities report power plant performance are included. Nuclear and coal capacity factors and economics are presented. The author disagrees with these figures, which indicate that coal-fired power plants have a marked advantage over nuclear plants. He argues that deaths from pit accidents and from pneumoconiosis would be avoided if nuclear power was used, and gives estimates of the cost of fatalities and of environmental degradation from pollution from nuclear and coal-fired power generation.

Struxness, E.G. Assessment of Impacts and the Preparation of Environmental Impact Statements for the Licensing of Nuclear Power Plants. (Oak Ridge National Lab., TN). Apr 1977,

The National Environmental Policy Act of 1969 (NEPA) established the nation's policy of protecting the environment. The Atomic Energy Commission (AEC) then, and the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC) now, have enlisted the aid of three national laboratories, including Oak Ridge National Laboratory (ORNL), to assist in the preparation of Environmental Impact Statements required by NEPA in connection with the licensing of nuclear power plants. The ORNL approach to the assessment of potential environmental impacts and the preparation of Environmental Impact Statements (EIS) for the NRC and the manner in which the EIS is used in NRC's licensing procedure are described.

Tajima, E. Development of Nuclear Energy and Protection of the Environment. (Rikkyo Univ., Tokyo (Japan)). (May 1975).

The consumption of energy is on the increase with the advance of civilization, which causes the pollution of the environment. Nuclear energy emerged as a means of preserving conventional fuel. It has two main aspects of environmental pollution, i.e. radiation and discharged heat. The pollution by radiation is described. There is an essential difference between nuclear pollution and conventional pollution. The environmental problems concerning

nuclear power involve not only those in nuclear power plants but also those of fuel cycle itself, such as fuel reprocessing, transportation and waste disposal.

Thomas, J.M.; L.L. Eberhardt. Ecological Impact Assessment. (Battelle Pacific Northwest Labs., Richland, WA). 1975.

Quantitative problems associated with "ecological impact assessment" with particular reference to defining population effects are discussed. Under the assumption that site-by-site evaluation will continue, some comments on the two approaches most commonly used, the experimental and simulation models, are offered along with some alternatives. Judgments of ecological impact are not quantitatively defensible but are qualitative, subjective, or political in nature. It is suggested that an examination of aggregated data from various nuclear power plant sites may be one way to obtain enough replication to judge ecological impact. Currently available data from such studies as well as appropriate demographic, vegetation, census, and bibliographic material could offer an interesting challenge to computer professionals if such an undertaking were contemplated. A description is given of the research programs at PNL and how computers are now involved. Future possibilities and directions are discussed.

Thomas, J.M. Factors to Consider in Monitoring Programs Suggested by Statistical Analysis of Available Data. (Battelle Pacific Northwest Labs., Richland, WA). pp 243-255 of Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations. Van Winkle, W. (ed.). Elmsford, NY; Pergamon Press Inc. (1977).

Based on experience gained in the statistical analysis of data collected during monitoring programs at three nuclear power plants, as well as on other studies in the area of impact assessment, I have attempted to outline what has been done and what I believe can be done in assessing environmental changes. Procedural changes that I suggest include the implementation of a stopping fuel so field studies are terminated after a negotiated period of time and the commitment of all resources to studies of one or two species. Simulation models are suggested as a useful tool in an iterative process where results of field studies are routinely incorporated until a negotiated stopping time is reached or until acceptable results are attained. Finally, I describe the statistical analyses we have used and their limitations, and I give some sample-size estimates needed to detect changes of specified sizes in population numbers. To detect changes in population number of the size we have encountered, calculated sample sizes are found to be much larger than in current use.

Thorhaug, A. Ecological Study of the Effects of Power Plants on Benthic Macroplant Microcosms in Subtropical and Tropical Estuaries. Progress Report, 1976-1977. (Miami Univ., Key Biscayne, Fla. (USA). Dept. of Microbiology). Aug 1977. p. 34.

The effect of two fossil fuel and two nuclear plants on a near-shore seagrass community was studied in South Biscayne Bay, Dade County, Florida, over the past four years. The focus of the study was to delineate the effects that a series of various pollutants have had on the dominant system of seagrass *Thalassia testudinum* and its related community. Data are included from studies on the effects of heavy metals, waste heat, and dredging activities, with emphasis on thermal pollution. In order to separate the perturbation of the specific pollutant from the natural fluctuations of the system, efforts were made to understand the dynamic processes in adjacent untouched areas.

Van Winkle, W. Jr. Application of Computers in An Assessment of the Environmental Impact of Power Plants on an Aquatic Ecosystem. (Oak Ridge National Lab., TN). 1975.

The application of computers in the area of power plant impact assessment is approached from the standpoint of addressing a representative and important species, the striped bass, which is subjected to numerous stresses by virtue of the operation of five power plants along the lower Hudson River in New York State. Four particular applications of computer usage are discussed: (1) bibliographic information services; (2) data management; (3) data analysis; and (4) simulation modeling.

Volders, R. Potential Effects of Nuclear Installations on the Physical and Human Environments. (Hydro-Quebec, Montral (Canada)). pp 17 of Challenge of Nuclear Energy to Quebec Industry. Proceedings of first Augustin-Frigon symposium, May 12, 13 and 14, 1976, Session II, Paper 2. (In French).

Thermal effluents from nuclear power plants have some aquatic and atmospheric effects. In aquatic ecosystems, sharp changes in temperature are more disrupting than the small increases in temperature prevailing in Canadian conditions. The rejected heat must be utilized in the long term, probably for district or process heat. Radioactive effluents are well within international guidelines but the public conception and imperfect scientific understanding of chronic low dose irradiation effects are a severe hindrance to nuclear power proliferation. Nuclear power has non-radiological human effects due to its high technological nature, demand for services, skilled labor, and capital, and preference for sparsely populated sites.

Wijker, H.; N.V. Kema. Planning of Combined External Irradiation and Internal Contamination to Reduce Dose in Nuclear Power Plant Operations. pp 451-454 of Proceedings of the 4. International Congress of the International Radiation Protection Association. Paris, 24-30 April 1977. Vol. 1. Fontenay-aux-Roses, France; Association Internationale de Protection contro les Rayonnements (1977).

In nuclear power plants many operations have to be carried out in high radiation fields under cramped working conditions. By omitting the hampering wearing of protective breathing apparatus, work can be speeded up and doses from external irradiation reduced. However, a dose from internal contamination is added. If this is accepted in dose planning as a tool to reduce total dose, a practical system has to be derived. A system worked out by Jacobi (1974) can be used as a base to serve this purpose. For each organ, the dose is multiplied by a special factor f to obtain a reduced dose giving the same risk as this dose from a uniform total body irradiation. Reduced-dose reserves can be introduced for planning purposes. After description of such a dose planning system, the dose reduction factors f are discussed. Instead of basing them solely on hurt-or-suffering risks as done in ICRP-publ. 13 and by Jacobi, also the differences in latent and risk periods for leukemia and other cancers are introduced for young radiological workers as well as the shortening of risk periods by life expectancy, when considering yearly maximum permissible doses from 18 till 65 years of age. Systems of values of f derived from risks published in ICRP-publ. 13 (1966), UNSCEAR-report 1972, BEIR-report (1972) and by Jacobi (1974) are compared.

Willard, B.E. Guidelines of the Council on Environmental Quality for the Preparation of Environmental Impact Statements. pp 233-246 of In Environmental Impact of Nuclear Power Plants. Karam, R.A. (ed.). Elmsford, NY; Pergamon Press, Inc. (1976).

Some topics discussed are as follows: principles of ecology; the national environmental policy act; CEQ guidelines for measuring agency implementation of NEPA; cost-benefit analysis of energy sources; and short-range commitment or resources vs. long-range values of resources.

NUCLEAR POWER PLANT-GENERAL INFORMATION

. ATW Statistics: Nuclear Power Stations 1975 - A Worldwide Survey. (Mar 1976). (In German).

The new atw statistics contain four columns of survey data of the world's nuclear power stations arranged by countries and by reactor manufacturers, state as of December 31, 1975, the orders for nuclear power stations placed in 1975, and the electricity generation of the plants currently in operation. According to this survey, 173 nuclear generating units with a total capacity of 71,000 MWe were in operation worldwide in late 1975, another 353 units with 323,000 units with 323,000 MWe were either under construction or ordered.

. Status of Central Station Nuclear Power Reactors: Significant Milestones. (Energy Research and Development Adminis- tration Washington, D.C. (USA). Div. of Nuclear Research and Appli- cations). 1 Jul 1976. p. 13.

. U.S. Central Station Nuclear Electric Generating Units: Significant Milestones. (Energy Research and Development Administration, Washington, D.C. (USA). Div. of Nuclear Research and Applications). 1 Jul 1977. p. 15.

Agee, L.J. A Proposed EPRI Executive System and Data Base. Special Report. (Electric Power Research Inst., Palo Alto, Calif. (USA)). Nov 1975. p. 50.

This report summarizes the long range objectives of EPRI Nuclear Power Division in the area of developing a viable data base and interacting computer programs. The data base considered will contain both experimental and analytical data. The computer programs considered may be simple programs to reduce data or sophisticated computational systems for solving problems such as LOCA or reactor physics calculations of an LWR. In addressing these problems, both the type of computers available and existing executive systems were studied. Of equal importance were the type and physical locations of the potential users, EPRI, the electric utilities, and the general nuclear community at large. The use of this system should assure an orderly and timely transmittal of data from the researcher to the many different users in a simple, well documented and easily accessible manner.

Crockett, P.W. Nuclear Power Plants: Ecology and Health Physics
(A Bibliography With Abstracts). Report for 1964-Nov 77. (National
Technical Information Service, Springfield, Va. (USA)). Dec 1977.
p. 217.

A compilation of references is presented on subjects related to the environmental impact of nuclear power plants. The following topics are included: radiation dosage and hazards to animal life and humans; radiation exposure through food chains; radiation monitoring of the ambient environment and protection to personnel and surrounding populations; the effects of thermal pollution, and entrainment of aquatic animals. (This updated bibliography contains 212 abstracts, 54 of which are new entries to the previous edition.)

Rockville, MD; Commercial Nuclear Power Plants. Edition No. 10.
(1978). p. 64.

An updated volume of statistical information on commercial nuclear power plants operating, or under construction, in the United States today is presented. Revised yearly, the publication is intended to be a handy reference guide to basic information on nuclear units.

Schwarz, O. Steam Power Plants - Nuclear Power Plants. (VGB Technische
Vereinigung der Grosskraftwerksbetreiber e.V., Essen (F.R. Germany)).
(Jan 1976). (In German).

An introduction is given into a bibliography concerned with the main problems of power plant construction and power plant operation.

APPENDIX H
NATURAL GAS BIBLIOGRAPHY

ECONOMICS
ENVIRONMENTAL EFFECTS
GENERAL INFORMATION

Economics

. Washington, D.C. Energy Information Report to Congress. Quarterly report: first quarter 1978. (Department of Energy, Washington, DC (USA). Energy Information Administration). Jul 1978. p. 93.

Detailed data are compiled on energy in the United States. Oil and gas exploration and development are covered in Section 2. Section 3, Coal, covers information on production, consumption, stocks, imports, exports, and reserves. Natural gas data are compiled in Section 4. Section 5 on petroleum covers the following: supply and demand, crude oil production, imports, refinery input and output, demand by type of product, inventories, and crude oil allocation program. Section 6 on nuclear energy covers: status of domestic nuclear power plants; operating power plants; nuclear power plant construction programs; capacity projections and requirements; supply of nuclear fuel materials; and policy, decisions, and issues. Sales of electricity, imports and exports, production of electricity, primary energy consumed by power plants, power plant conversion efficiency, and fuel stocks at power plants are data covered in the last section on electric power.

. Redondo Beach, California. Energy Options for Industry. Final report. (TRW Energy Systems Management Div., Redondo Beach, Calif. (USA)). 17 Jan 1977. p. 132.

This report is directed at supplying California Energy Resources Conservation and Development Commission with background information on potential shifts from gas to alternate sources of energy with major emphasis on large industrial gas users. Solar and geothermal energy may have some impact in the future, but presently oil will be the major substitute. The California Public Utilities Commission established an end-use curtailment plan designed to direct the supply of gas; details of this plan are summarized. In Section 2, the climate meteorology and the main features of air quality control regulations are discussed. Section 3 examines the alternate energy sources and feedstocks and indicates the procedure by which an industrial user would assess the technical and economic impact of switching from natural gas for his operation. Section 4 is devoted to California's largest industrial consumers of natural gas; it contains specific information on how the gas is used and under what conditions the gas could be replaced by alternate sources. Section 5 summarizes the major factors influencing decisions facing an industrial user when he selects alternate sources of energy or feedstock. Appendix A is a detailed description of the air pollution history and status as it applies to California, considering both California and Federal pollution legislation. A glossary of the technical terms used in the report is included.

Energy Situation in The Community: Situation 1976, Outlook 1977.
Luxemburg; Commission of the European Communities (1977). p. 31.

Following a chapter summarizing the energy situation for 1976 and the outlook for 1977, the economic situation, the demand for energy, and the market situation and outlook are discussed in detail. Briefly, results for 1976 showed an economic recovery as compared with 1975, but the outlook for 1977 was guarded. Detailed data are provided for petroleum, natural gas, coal, electricity, and nuclear fuels in the common market countries.

Washington, D.C. Federal Role in Natural Gas Distribution Rate Structure Reform. (Resource Planning Associates, Inc., Cambridge, Mass. (USA)). Jun 1977.

This report reviews the rate structure policies of the natural gas distribution industry and assesses the need for reform in this policy area. The study considers the cost structure and rate structures of the gas distribution industry, and evaluates program options for involvement of the Federal Energy Administration in rate structure reform. The results of the study are oriented toward identifying the problems and the general nature of appropriate FEA actions to address these problems.

Arlington, Virginia. Oil and Gas Replacement Cost: Development and Production. Volume I. Discussion of methodology, exhibits, and projections. Final report. (Gruy Federal, Inc., Arlington, Va. (USA)). 5 Aug 1977. p. 101.

The Federal Energy Administration (FEA), other Governmental agencies, Congress, and industry are affected by the mandate of the Federal government to provide for prices that reflect the true replacement cost of oil and gas. The Office of Oil and Gas has, therefore, contracted for a series of studies on Oil and Gas Replacement Cost. The study was conducted to project the development and production costs by region and well depth interval for the benchmark years 1980, 1985, and 1990. The identification and collection of reliable and consistent historical series disaggregated to these levels is considered essential to the generation of accurate and viable forecasts of replacement costs for oil and gas production systems. Twenty-four geographical regions were specified and six depth classes. A clear delineation is drawn between the cost of drilling and completing development wells and the cost of operating producing wells. Development well costs are projected on a cost per foot basis. Operating costs of producing wells are projected on a cost per month basis.

Arlington, Virginia. Oil and Gas Replacement Cost: Development and Production. Volume II. Exhibits. Final report. (Gruy Federal, Inc., Arlington, Va. (USA)). 5 Aug 1977. p. 294.

Data tables are presented relative to the replacement cost of petroleum and natural gas in the USA for the benchmark years 1980, 1985, and 1990.

. Washington, D.C. Oil and Gas Resources, Reserves, and Productive Capacities. Volume I. Final report. (Federal Energy Administration, Washington, D.C. (USA)). Oct 1975. p. 74.

This report provides final reserve and productive capacity estimates, compares these estimates with estimates from other sources, projects a U.S. crude oil productive capacity estimate, evaluates the procedures used to develop these estimates, and recommends procedures to be used for future estimates.

. Washington, D.C. Oil and Gas Resources, Reserves, and Productive Capacities. Volume II. Final report. (Federal Energy Administration, Washington, D.C. (USA)). Oct 1975. p. 160.

The Federal Energy Administration Act directs the FEA to prepare a complete and independent analysis of actual oil and gas reserves and resources in the United States and its outer continental shelf. Volume I of this final report provides final reserve and productive capacity estimates, compares these estimates with estimates from other sources, projects a U.S. crude oil productive capacity estimate, evaluates the procedures used to develop these estimates, and recommends procedures to be used for future estimates. Volume 2 provides summaries of engineering analyses of major domestic oil and gas fields.

. Chicago, Illinois. Outlook for New Sources of Gas Supply. (Institute of Gas Technology, Chicago, Ill. (USA)). 1976. p. 76 of Gas Technology.

Included are presentations from 5 speakers: Dr. William T. McCormick, Jr., Director, Office of Commercialization, ERDA; Dr. Vincent E. McKelvey, Director, U.S. Geological Survey; Dr. Gorman C. Smith, Ass't. Administrator for Regulatory Programs, FEA; Mr. J. Wade Watkins, Deputy Director, Division of Oil, Gas, and Shale Technology, ERDA; and Dr. Herman Enzer, Director, Office of Minerals Policy and Research Analysis, U.S. Dept. of the Interior. On completion of the presentations, the speakers were assembled as a panel for a group discussion, moderated by Dr. James J. Brophy, senior vice president, Institute of Gas Technology. There was a luncheon address by John H. Holloman III, Vice Chairman, Federal Power Commission. Dr. McCormick addressed the problem of replacing conventional supplies of gas with synthetic gas, arctic gas, LNG, etc. Dr. McKelvey discussed the possibilities of gas supplies in new offshore areas pointing out that 4.3 trillion ft were produced on the continental shelf in 1975. Dr. Smith's presentation was concerned with the problems of total supply and distribution of available supplies, particularly the role of the FEA in getting gas out from under boilers where coal, and in some cases oil, can be substituted. Mr. Watkin's topic was Enhanced Onshore Recovery of Natural Gas, covering the following: tight formations, geopressured aquifers, coal beds, landfills, and gas hydrates. Dr. Enzer,

who headed the Interior Department's study of alternate routes for delivery of Alaskan gas to the Lower 48 States, assessed the potential supply of Alaskan and Canadian Arctic gas. It was concluded that the potential for new sources of supply is there; improved technology is an issue, but not the dominant one. The dominant issue is to provide the consumer with a choice of energy sources; to do this, all potential sources of gas supply must be examined.

. Washington, D.C. Project Independence Evaluation System (PIES) Documentation. Volume IV. FEA model of oil and gas supply: data validation and update. (ICF, Inc., Washington, D.C. (USA)). Sep 1976. p. 52.

A detailed and comprehensive discussion is presented of the oil and gas supply model which is used to construct the oil and gas supply curves which are used by PIES. An overview description of the model and the modeling methodology as well as details on the data input requirements are also presented.

. Washington, D.C. Project Independence Evaluation System (PIES) Documentation. VIII. Methodology for enabling the PIES oil and gas supply curves to respond to non-constant prices. (Federal Energy Administration, Washington, D.C. (USA)). Sep 1976. p. 41.

A study was conducted to address the possibility of increased capability of the FEA oil and gas supply modeling system to respond to non-constant price trajectories, rather than constant, instantaneous patterns. More specifically, it is intended to investigate the efficacy of enabling the FEA oil and gas supply models to respond to prices that are ramped, especially in the short run. The reality of a schedule of ramped prices has been demonstrated in the Energy Policy and Conservation Act of 1975 (EPCA).

. Washington, D.C. Report of the Transmission, Distribution, and Storage Technical Advisory Task Forces: Impact of Gas Shortage on Consumers. (Federal Power Commission, Washington, D.C. (USA)). Sep 1976. p. 56.

The advisory task force was asked to analyze the predicted shortage of natural gas, its probable impact on residential, commercial, and industrial customers, and possible methods of ameliorating any adverse effects. It was found that forced supply curtailments began in 1970 and have increased rather dramatically to an average predicted value of 22 percent for the 1976-7 heating season (for some pipeline companies the value was 30 to 40 percent of requirements; the problem is severe with some interstate pipelines serving a large industrial sector and large residential population). So far the results have not been serious because of warm winters and industrial recession. The impact of curtailment on various industries is examined. In many cases the use of gas is critical in various processes and the only feasible alternative is propane. Some companies have either bought their own supply of natural gas

or converted to coal or fuel oil. Among others the petrochemical industry would be severely affected by natural gas curtailment. The result would be decreased production, unemployment and decreased competitiveness. Residential consumers have so far been protected from adverse effects by regulatory priorities, price regulation and gas company efforts to supplement supplies with propane, LNG, storage facilities, etc. However, gas distributors now refuse new customers. Therefore, the burden falls on builders and new home buyers, who must seek alternative energy supplies at higher cost. Voluntary conservation efforts appear to be saving 4 to 8 percent.

. Bartlesville, Oklahoma. Western Gas Sands Project Status Report. (Energy Research and Development Administration, Bartlesville, Okla. (USA). Bartlesville Energy Research Center). 1 Nov 1977.

The Western Gas Sands Project Plan, Project Implementation Plans and Project Plan Document FY 78 are in various stages of preparation. Information gathering by U.S. Geological Survey (USGS) of the initial data base for many of the project activities is nearing completion. Some base maps are complete and field investigations in the principal areas of interest are being conducted. Research and development by Energy Research Centers and National Laboratories were directed toward new tools and instrumentation systems, rock mechanics experiments, mathematical modeling, and data analysis. The Uinta Basin in Utah and Piceance Basin in Colorado have ongoing massive hydraulic fracture (MHF) experiments in the Upper Cretaceous tight gas formations. These are: CER Corporation, MHF 3; Gas Producing Enterprises, Natural Buttes No. 14, 18, 19, 20; Mobil Oil, F-31-13G; and Rio Blanco Natural Gas, 498-4-1. Colorado Interstate Gas Company has been awarded a contract to determine if productivity in low permeability reservoirs can be improved by reducing the interstitial water saturation. They will be using two wells, the Sprague No. 1 and Miller No. 1, completed in the Dakota J formation in the Wattenberg Field in north central Colorado. All of the massive hydraulic fracture wells, with the exception of the Pacific Transmission well, have been fractured as planned. The Mobil and GPE No. 14, 18, and 20 wells show significant improvement as compared to original flow rates. The Mobil well is being tested for additional MHF treatments. Sandia Laboratories is continuing their research program in hydraulic fracturing at DOE's Nevada Test Site(NTS).

Ayer, H.W. and D.J. Cormier. Impacts of Increasing Energy Scarcity in Irrigated Agriculture: An Empirical Study from the Arid Southwest. (Univ. of Arizona, Tucson). pp. 709-718 of In Energy use management. Vol. I. Frazzolare, R.A. (ed.). Elmsford, NY; Pergamon Press Inc. (1977).

Increasing natural gas curtailments and rising natural gas and electricity prices threaten to seriously affect irrigated agriculture where these fuels are used to pump water. In arid Pinal

County, Arizona, the current cost of electricity to pump water is from 18 to 25 percent of total variable costs, and typical farms pay \$25,000 per year for electricity. Thus, the purpose of the research is to estimate the impacts of increasing gas curtailments and rising gas and electricity prices on farm profits, and on adjustments in crop patterns water and energy use which should be made in response to greater energy scarcity. The research is based upon 1976 and 1977 data for Pinal County farms. Farms are divided into four size categories, from 131 to 2,596 cropland acres, and for each size the analysis is done for three well depths, 395 to 555 ft. Linear programming is used to estimate the profit maximizing acreage of alfalfa, Upland cotton, Pima cotton, barley, wheat and milo, and the profit maximizing level of water and energy use as natural gas is curtailed by up to 30 percent and the price of natural gas and electricity increases by 10, 25, 50, 100 and 200 percent, respectively. Implications are given for both on-farm and national and regional policy. 28 references.

Backhaus, H. and F. Papmahl. Small Ammonia Plants: Prospects for Natural-gas Utilization in Developing Countries. (LGA Gas and Mar Consult, Remagen-Rolandseck, Ger). *Erdoel-Erdgas Z.*; 93: No. 3, 93-99(Mar 1977).

The authors examine the potential of small ammonia plants--delivered by industrialized countries on a turnkey basis and erected on floating structures--for improving fertilizer supplies in developing countries. Compared with large, locally built ammonia complexes, small barge-mounted plants offer the advantages of short delivery and greater adaptability to the domestic ammonia market and its growth. In addition, smaller plants can produce surplus ammonia for exports, thus providing foreign-exchange money to finance the necessary investment expenditure.

Bass, A.F. Curtailments of Natural Gas Service. (National Energy Information Center, Washington, D.C. (USA)). Feb 1976. p. 13.

The issue of natural gas supply and potential curtailments is a complicated and sometimes confusing subject. A clarification of this issue is presented by summarizing and discussing basic relevant information. This includes an explanation of commonly-used terminology, a discussion of some of the causes of the current supply-demand imbalance, a description of the curtailment priority systems, a presentation of the estimated extent of gas curtailments, and a review of major remedial actions. The curtailment of natural gas in the interstate market results from the long-term of declining reserve additions. The immediate extent of the curtailments varies greatly by State as does the capability to adjust to the shortages. Recent weather, adjustment of priority plans, conservation practices, and emergency purchase of gas under FPC regulations have combined to significantly reduce or alleviate the projected impacts during the current winter. However, these short-term measures do not materially address the longer-term issue of the natural gas supply-demand imbalance.

Becker, H.S., J.G. Stover, H. Gerjuoy and T.J. Gordon. Assessment of Socioeconomic and Demographic Determinants of Electrical Energy and Gas Consumption in California. Volume III. A summary of some important trend forecasting techniques. (Futures Group, Glastonbury, Conn. (USA)). Dec 1976.

The material presented in this volume summarizes the primary features of some of the important techniques which are available for projecting or forecasting trends such as those treated in this study. It is intended that these summaries provide insight into such techniques so that those interested may investigate them further, especially by obtaining the references listed in each summary. The summary for each technique includes descriptions of the output format; input requirements; forecasting period that can be treated; procedure involved in using the technique; major strengths; major limitations; initial development and use of the technique; and selected applications. An introduction treating the nature of trend forecasting and an overview of all the techniques also is presented as a vehicle for quick comparison among them. Curve fitting, simulation modeling, and event-modified techniques are included.

Berndt, E.R., M.A. Fuss and L. Waverman. Dynamic Models of the Industrial Demand for Energy. (Economics Research Group Ltd., Toronto, Ontario (Canada)). Nov 1977. p. 147.

Econometric approaches to modeling the demand for electricity, petroleum, coal, and natural gas by the manufacturing sector of the U.S. economy are investigated. Important aspects of the research are incorporation of dynamic effects as well as an introduction of the impact of technological change on energy usage. The first model analyzed is the ad hoc partial adjustment model applied to a system of equations. Extending the work of Rosen and Nidiri (A.E.R. 1969) and Berndt and Savin (Econometrica, Sept./Nov. 1975), the authors show that ad hoc models applied to flexible functional forms such as the translog or generalized Leontief have a number of undesirable features: (1) short-run own-price elasticities may exceed long-run elasticities, thus violating the Le Chatelier principle; and (2) for the translog, if the adjustment matrix is diagonal, all rates of adjustment must be equal; specification of a general adjustment matrix leads to underidentification of the adjustment parameters. The above two problems and others are illustrated using data drawn from U.S. aggregate manufacturing 1948 to 1971. A second model is developed from the cost-of-adjustment literature associated with R. Lucas and A. Treadway. It is shown that the Lucas and Treadway models can be implemented empirically to overcome the theoretical objections to the ad hoc partial adjustment models. In particular, the econometric model cannot violate the Le Chatelier principle and contains a generalized endogenous (non ad hoc) partial adjustment mechanism. An analysis of the effects of an investment tax credit on both the long-run demand for energy and the adjustment path to the new long-run equilibrium demand

is made. Several models are considered that can be utilized in an analysis of endogenous technical change. The most promising model for future research is one which incorporates knowledge as a quasi-fixed factor within the cost of adjustment framework.

Bischoff, G. Future Value of Fossil Primary Energy Carriers in our Energy Economy. (Koeln Univ. (Germany, F.R.). Geologisches Inst.). pp. 21-23 of Energy and environment. Essen, Germany, F.R.; Vulkan-verl. (Jun 1977).

A brief survey is presented of the possibilities of the primary energy carriers to meet the world's rising energy demand. The author starts from the assumption that the annual growth in energy consumption will be around 4%, and that by the turn of the century the demand for fossil energy carriers will be twice as high. In meeting this demand, petroleum is only assigned a passing significance. However, for natural gas, too, the limits of its availability are in view, though in the distant future the USA and Western Europe will have the chance of supplying the natural gas network with coal gas. The extent of the reserves in black coal (and in brown coal) and the possibilities of coal gasification make this energy carrier the most important fossil energy carrier in the future. The main problems of future energy supply do not only concern the extent of the reserves, but above all their uneven distribution and conflicts resulting therefrom.

Cicchetti, C.J. End-user Pricing of Natural Gas. (Wisconsin Public Service Commission, Green Bay); Wiener, D. Public Util. Fortn.; 101: No. 6, 11-15(16 Mar 1978).

The paper focuses on the alternative end-use tariff structures for natural gas. Emphasis is on marginal-cost pricing. First, there is a brief description of traditional natural gas pricing structures. While there is considerable variability between utilities, all do contain some common features. The second section contains a discussion of these tariff structures. Following are discussed the purposes of marginal-cost pricing, the advantages of pricing signals, and residual, but other equally important advantages. The final section deals with some of the problems with marginal-cost pricing, specifically the questions of excess revenues and fairness.

Drysdale, F.R. and C.E. Calef. Energetics of the United States of America: An Atlas. (Brookhaven National Lab., Upton, N.Y. (USA)). Oct 1977.

In this update, a description of the United States' energy system is presented in the form of thirty-one maps and eight major tables. The county has been chosen as the basic unit for reporting estimations of many energy, demographic and economic variables. The variables include production of all fuels (including hydroelectricity), uses of fuels and electricity broken down by sector and end-use, existing and planned electricity generation capacity,

fuels such as oil sands and shales are discussed, as well as renewable resources such as solar, geothermal, and hydroelectric energy. The book contains a detailed global data base, global resource overviews, a discussion of the situation of developing countries, and studies of supply availability in thirteen major consuming countries (Canada, Denmark, Finland, France, German Federal Republic, Italy, Japan, Mexico, Netherlands, Norway, Sweden, United Kingdom, and the United States).

Ode11, P. Energy. Needs and Resources. (Erasmus Universiteit, Rotterdam (Netherlands)). Basingstoke; Macmillan Education (1977). p. 34.

The size of the likely energy resources is evaluated, and the rate of increase of demand. Particular attention is paid to the future availability of oil and natural gas, but coal is also considered in detail. It is concluded that massive development of alternative sources of energy will not be required until the second quarter of the twenty-first century at the earliest. Research should continue into fusion and solar energy as the long-term alternatives to conventional energy sources. In the meantime, it is stated, we can severely restrict the degree to which fission nuclear power is developed.

Othmer, D.F. Acetylene and Acetylene-chemicals from Natural Gas. (Polytech Inst of NY, Brooklyn). Verfahrenstechnik (Mainz); 11: No. 6, 377-380(Jun 1977).

Acetylene stores in the triple bond joining its two carbon atoms a great deal of energy--so far most of this has come from the electrical energy used in the furnace which makes from lime and coke the calcium carbide which is then hydrolyzed to give acetylene. In making acetylene from hydrocarbons the large amount of energy is absorbed from a high temperature combustion, or partial combustion, or an electric arc. This reactivity resulting from the triple bond and the large amount of stored energy makes acetylene combine very readily with other materials to give, among the large number of possible derivatives, many petrochemicals. The Happel-Kramer acetylene process is described. 5 refs.

Pelto, C.R. (ed.). Energy Information: Report to Congress. Quarterly report: first quarter 1977. (Federal Energy Administration, Washington, D.C. (USA); National Energy Information Center, Washington, D.C. (USA)). 1977. p. 118.

Data are compiled on energy sources in the United States for the First Quarter 1977. Gains in total resource developments are discussed. Data on production, consumption, stocks, imports, exports, transportation, and reserves of coal are summarized. Data on natural gas and NGL are provided followed by data on supply and demand, production, imports, exports, refinery activities, inventories, allocations, and reserves for petroleum. Information on the status of domestic nuclear power plants, construction,

operating plants, capacity projections and requirements, supply of nuclear fuels materials, and policy decisions is included. Electricity consumption, imports and exports, production, primary energy consumed and stockpiled by power plants and power plant conversion efficiency are presented. Data on hydropower are tabulated.

Siddayao, C.M. The Natural Gas Shortage. Final report. (George Washington Univ., Washington, D.C. (USA). Energy Policy Research Project). Jul 1975. p. 41.

This report traces the history of well-head controls over the prices of natural gas. It analyzes the reasons for these controls and then assesses their impact on investment in exploration and production in the industry.

Stickles, R.P., E. Interest, J. Kittrell and T.I. Moncrieff. Assessment of Fuels for Power Generation by Electric Utility Fuel Cells. Final report. (Little (Arthur D.), Inc., Cambridge, MA (USA)). Mar 1978. p. 192.

This study assesses the technical and economic feasibility of alternate fuel options for dispersed and baseload utility-scale fuel cell power plants. The assessment covers coal-derived and petroleum-derived fuels, and near-term and advanced fuel conversion and fuel cell technologies. A forecast of international crude oil prices over the period of 1980 to 2000 is developed. Three oil-based dispersed fuel cell and six coal-based central fuel cell power plants were characterized in terms of process conditions, energetics, and cost. The projected prices and availability of naphtha for first generation dispersed fuel cells are favorable based on the forecasted incremental demand profile for petroleum products. The optimum sulfur level for refined petroleum products purchased for dispersed fuel cells is order-of-magnitude 200 ppm sulfur. Molten carbonate fuel cells integrated with near term coal gasifiers show promise for economical and efficient baseload power generation. Synthetic liquid fuel derived from coal is not competitive with petroleum-derived fuels in the 1980 to 1990 time frame.

Vogt, D.P., P.L. Rice and V.P. Pai. Energy Availabilities for State and Local Development: 1974 Data Volume. (Oak Ridge National Lab., Tenn. (USA)). Nov 1977.

This report is one of a continuing series developed by ORNL with financial support from the Economic Development Administration to present the supply, demand, and net imports of seven fuel types for four final consuming sectors of BEAs, states, census regions, and the nation in 1973. The data are formatted to present regional energy availability from primary extraction as well as from regional transformation processes. As constructed, the tables depict energy balances between availability and use for each of the specific fuels. The long-term objective of the program is to pinpoint those regions where economic development potentials

will most likely be affected by the availability of energy. This information coupled with specific knowledge of projected economic growth and employment distribution patterns can assist EDA in developing its grant-in-aid investment strategy.

Williams, L.J., J.W. Boyd and R.T. Crow. DEMAND 77: EPRI Annual Energy Forecasts and Consumption Model. Volume 1. Forecasts and general description of the model. (Electric Power Research Inst., Palo Alto, Calif. (USA)). Mar 1978. p. 77.

This report presents forecasts of end-use consumption of electricity, petroleum, natural gas, and coal for the years 1980 to 2000. The forecasts are based on an econometric model whose equations represent energy consumption of each form of energy in each end-use sector. The forecasts are based on a forecast of long-run economic growth coupled with three scenarios concerning energy prices and conservation policy. Each of the scenarios was coupled with two scenarios concerning natural gas availability, one in which natural gas supplies are restricted at the assumed price and the second in which natural gas is freely available at the assumed price. The scenarios were: (1) a baseline scenario, which assumed that the most likely energy prices would prevail and that no significant new conservation policies would be adopted; (2) a high-electricity-consumption scenario, with low oil prices and minimal obstacles to the use of coal and nuclear energy for electricity generation; and (3) an energy-conservation scenario, which embodied the proposals in President Carter's National Energy Plan. Forecasts are presented for each of the sectors and for each of the forms of energy by five-year periods. The structure of the econometric model is described along with plans for further development.

Environmental Effects

. Washington, D.C. Natural Gas Emergency Standby Act of 1975. Draft Environmental Impact Statement. (Federal Energy Administration, Washington, D.C. (USA)). Nov 1975. p. 314.

This report is the draft environmental impact statement on the proposed Natural Gas Emergency Standby Act (NGESA) of 1975. The proposed legislation was submitted to the Congress on September 10, 1975. The purpose of the statement is to describe and analyze the environmental and energy impacts that would result from the implementation of the proposed legislation or from alternatives to that legislation. This report contains a background on the natural gas shortage, descriptions of proposed legislation concerning natural gas, a description of the natural gas situation, a description of the environment affected and impact methodology, energy and environmental impacts of the proposed legislation concerning natural gas, adverse environmental impacts, short-term uses of the environment and long-term productivity, alternatives to proposed natural gas legislation, and commitment of natural gas resources.

. Columbia, Maryland. Toxic Trace Pollutant Coefficients for Energy Supply and Conversion. Final report. (Hittman Associates, Inc., Columbia, Md. (USA)). 30 Sep 1977.

The motivation for this study was the recognition by the Energy Research and Development Administration (ERDA) of a need to focus attention on not only the major pollutants but also the toxic trace pollutants from energy supply, conversion and end use activities. This study addresses and quantifies approximately 44 toxic trace air and water pollutants that are generated by energy supply and conversion activities. The study builds upon previous work done by the Council on Environmental Quality, the Environmental Protection Agency and the National Science Foundation. The toxic trace pollutant data base generated by this study will become an integral part of the Energy Model Data Base (EMDB) maintained by ERDA. The study is complete only in that it addresses all energy supply and conversion activities. However, a need remains to address the toxic trace pollutants generated in the energy end use and industrial process sectors of the economy. The data contained in this report are being placed in a computerized retrieval system at Brookhaven National Laboratories (BNL). The BNL computer presently allows for rapid analysis of the environmental residuals produced by various energy systems.

Conner, W.H., J.H. Stone, L.M. Bahr, V.R. Bennett and J.W. Day, Jr.
Oil and Gas Use Characterization, Impacts, and Guidelines.
(Louisiana State Univ., Baton Rouge (USA). Center for Wetland
Resources). Jun 1976. p. 160.

A nontechnical survey of oil and gas activities and their impacts on wetland, and a discussion of preliminary guidelines for optimizing production and minimizing impact are presented.

Ernst, W. Experiences with Gassing of Plants. (Univ Tuebingen, Ger).
Gas- Wasserfach, Gas-Erdgas; 117: No. 10, 433-439(Oct 1976).

Effects of natural gas on plant growth are investigated. Methane content of soils is determined and found to be proportional to gain in crop weight both in greenhouses and field. 6 refs.

Mitchell, R.I. (Battelle Labs., Columbus, OH), R.W. Cote, R.R. Lanese, and M.D. Keller. Survey of the Incidence of Respiratory Disease in Households Using Gas and Electric Cookery. p 13., Session V, Paper 4 of In Proceedings of the Third Conference on Natural Gas Research and Technology. White, J.W. (ed.). Chicago, IL; Institute of Gas Technology (1974).

A study was undertaken to determine the incidence of respiratory disease in households in a midwestern suburban middle-class community, in a relatively unpolluted area. The sample included 441 families, divided into two groups; those utilizing gas cookery and those utilizing electric cookery, Family health and demographic data were obtained from the participants. The period of the study was one year. Reports of acute respiratory illness were obtained through bi-weekly telephone calls to each of the households. The respondents were asked to report respiratory illness in any member of the household, and to indicate the presence or absence of a set of signs and symptoms. Ambient air was analyzed, indoors and outdoors, in a sample of the households, and pulmonary function tests were conducted on a 42 percent sample of the participants, representing both types of household. The results of the study are presented with regard to reported incidence of respiratory illness in the two types of household. AID analysis and multiple regression were carried out to determine the best set of independent variables as predictors of respiratory disease incidence. This is the first in a series of studies. Subsequent studies will follow-up the reported respiratory illness to ascertain objective signs of illness and obtain bacterial cultures. Similar studies are also contemplated in areas in which the ambient air is more heavily polluted.

Roxin, C.L. and M. Tinkleman. Potential for Conversion to Coal as a Fuel by Major Fuel Users in the Pennsylvania Counties of Bucks, Chester, Delaware, Montgomery, and Philadelphia. Final report. (Delaware Valley Regional Planning Commission, Philadelphia, Pa. (USA)). Dec 1974. p. 71.

This report identifies major fuel users in the Pennsylvania counties of Bucks, Chester, Delaware, Montgomery and Philadelphia. Their present fuel use is discussed and the potential for their conversion from oil and gas to coal as fuel is briefly assessed. Impacts on air quality and freight rail needs are also reviewed. Finally, the attitudes of these industries toward conversion is discussed, particularly in reference to local reaction to national issues and policies.

General Information

. Washington, D.C. Crude Petroleum, Petroleum Products, and Natural Gas Liquids: December 1974. (Bureau of Mines, Washington, D.C. (USA)). 18 Apr 1975. p. 35.

Data compilations are presented on the production of crude petroleum, products of natural gas processing plants, and the production and sales of fuels and refined products.

. Washington, D.C. Energy in Focus. Basic Data. Washington, DC; Federal Energy Administration (1977). p. 13.

This brochure presents tabulated data on U.S. energy production, consumption, and prices. These statistics reflect a number of energy trends in the United States for the past 25 years. General energy data include domestic consumption per capita by source; historical energy consumption patterns; domestic energy consumption by type of fuel, by economic sector, and by per capita by source; and total domestic energy production. Detailed data are compiled for petroleum, natural gas, coal, nuclear energy, and generation by source. Data on crude oil, motor gasoline, natural gas, and coal prices are included.

. Washington, D.C. Energy Information Report to Congress. Quarterly report: second quarter 1976. (Federal Energy Administration, Washington, D.C. (USA)). 1976. p. 126.

Percentage changes in production, net imports, and supply of energy (in Btu equivalents) in the second quarter of 1976 relative to the first quarter of 1976 and the second quarter of 1975 are summarized. Indicators of oil and gas exploration activity were mixed for the second straight quarter. Data on production, consumption, stocks, imports, exports, and reserves of coal are summarized. A complete picture of the natural gas situation and then data on petroleum and refined petroleum products are summarized. The status of nuclear energy is stated under the following topics: status of domestic nuclear power plants, operating power plants, nuclear power plant construction programs, supply of nuclear fuel materials, and environmental decisions and issues. Data on the electric utility industry are covered in the following areas: electricity consumption, imports and exports, electricity production, primary energy consumed by power plants, power plant conversion efficiency, and fuel stocks at power plants.

Washington, D.C. Staff Handbook on Natural Gas.
Department of Commerce (1976). p. 102.

Wherever a gas shortage develops, a considerable amount of information will exist on the availability and distribution of resources and their economic output. This Handbook is intended to provide the necessary tools to use this information in the conduct of three tasks: crisis assessment, crisis management, and relief planning. The management of this set of tasks requires judgment, and priority assignment is difficult. The last section of the Handbook provides a framework that will accommodate information and data available on the demand-supply situation in the state of equilibrium. A strategy can then be developed after agreement has been reached on the priorities and the progress can be continuously observed as the relief actions become effective. It is preceded by four sections that provide some of the building blocks essential to the understanding of the problems encountered in the development of a strategy. They are: technical and physical data; government organizations and procedures; governmental and industrial organizations; and the gas industry, alternate resources, and industrial users.

Costley, W.J. ESCOE Information Retrieval System. System Description and Operation. (Engineering Societies Commission on Energy, Inc., Washington, D.C. (USA)). Apr 1978.

The ESCOE Technical Information Retrieval System is described. The technical information needs of the ESCOE Resident Engineers in providing services to DOE were identified, and the information resources that best match those needs were examined. The Assessment of information needs resulted in the selection of an ESCOE information base. The best mix of information sources and services was selected, and a remote terminal was acquired to access those sources that are available as computerized data bases.

Hundemann, A.S. Natural Gas: Supply, Demand and Utilization. Volume 1. 1964-1975 (a bibliography with abstracts). Report for 1964-1975. (National Technical Information Service, Springfield, Va. (USA)). Jul 1977. p. 152.

Abstracts pertaining to natural gas supply and demand, industrial and residential consumption, fuel substitution, availability, costs, Government policies, and regulations are presented. Studies dealing with projections of natural gas use and the economics of supply and demand are included. (This updated bibliography contains 147 abstracts, none of which are new entries to the previous edition.)

Hundemann, A.S. Natural Gas: Supply, Demand and Utilization. Volume 2. 1976-June 1977 (a bibliography with abstracts). Report for 1976-June 1977. (National Technical Information Service, Springfield, Va. (USA)). Jul 1977. p. 169.

Abstracts pertaining to natural gas supply and demand, industrial and residential consumption, fuel substitution, availability, costs, Government policies, and regulations are presented. Studies dealing with projections of natural gas use and the economics of supply and demand are included. (This updated bibliography contains 164 abstracts, 105 of which are new entries to the previous edition.) See also NTIS/PS-77/0573, Natural Gas: Supply, Demand and Utilization. Vol. 1. 1964-1975.

Hutchison, V.V. Selected List of Publications on Petroleum and Natural Gas, ERDA--BuMines, July 1, 1975-December 31, 1976. (Energy Research and Development Administration, Bartlesville, Okla. (USA). Bartlesville Energy Research Center). Apr 1977. p. 44.

This selected list contains 172 entries citing petroleum- and natural gas-related publications of ERDA-Fossil Energy, ERDA-National Laboratories, and Bureau of Mines, during the period of July 1, 1975-December 31, 1976.

Lehmann, E.J. Natural Gas. Part 1. Supply, demand and utilization. (a bibliography with abstracts). Report for 1964-Jun 1976. (National Technical Information Service, Springfield, Va. (USA)). Jun 1976. p. 211.

Citations concerning the supply, demand, and utilization of natural gas are presented. These studies were selected in order to cover trends, industrial and residential consumption, fuel substitution, availability, costs, Government policies, and regulations. (This updated bibliography contains 206 sbstracts, 110 of which are new entries to the previous edition.) See also NTIS/PS-76/0499, Natural Gas. Part 2. Marine Transportation.

APPENDIX I

DUAL POWER PLANT BIBLIOGRAPHY

Dual Power Plants

Coupling of Thermal and Electric Power Generation Using Coal, Oil and Natural Gas As Fuel for Four Turbines and Boilers. Energy; 29: No. 5, 146-150(May 1977).

Design criteria for rational power utilization by choosing four, rather than one unit, for steam generation in a food processing plant are demonstrated.

Etude Du Marche Europeen Des Centrales Nucleaires Industrielles Pour La Production Mixte De Vapeur Et D'Electricite. (Study of the European market for industrial nuclear power plants for the mixed production of electricity and steam). Luxembourg; Communautés Europeennes (Aug 1975). p. 77.

The opportunity of developing the mixed production of electricity and steam from nuclear power plants in the nine countries of the European Community is studied. Both public distribution and autonomous production are envisaged. An attempt is made to estimate the potential market for district heating and for chemical, agricultural and alimentary, textile, paper, car manufacture and wood industries. The reactors considered are LWR reactors of at least 100MWth. Suggestions are given to overcome the difficulties and constraints that stand in the way of a nuclear solution.

Local Energy Centers. Diesel Eng.; 73: No. 794, 159, 160(Aug 1977).

A brief review is given of a conference on combined generation of heat and electricity held in cooperation with the public supply authorities in July, 1977, at Imperial College, London.

Philadelphia, Pennsylvania. Nuclear Plant Siting Study. Volume I. Final report, Jul 1975-Jun 1976. (United Engineers and Constructors, Inc., Philadelphia, Pa. (USA)). Jun 1976.

The criteria and methodology are presented for evaluating the siting of a nuclear power plant at Radford Army Ammunition Plant (RAAP) near Radford, VA. A detailed plant design is described utilizing the Process Energy Consolidated Nuclear Steam Generator (PE-CNSG) concept developed by the Babcock and Wilcox Co. The PE-CNSG is a 313 MWt pressurized water reactor with 12 modular once through steam generators located inside the pressure vessel. For this application it has been configured to export 570,000 lb/hr of

steam and 23 MW of electricity. Three candidate sites at Radford were evaluated and one site was selected as having the most favorable overall characteristics. This site was further evaluated and found to be viable based on supporting data. An economic analysis was performed comparing the PE-CNSG to an equivalent coal-fired plant. The report concludes that at the expected utilization level of 45% of full mobilization requirements, the nuclear system has a slight economic advantage versus the coal system. This advantage is increased at higher levels of production. No technological or sociological barriers which would preclude the implementation of the nuclear system were identified.

. Philadelphia, Pennsylvania. Nuclear Plant Siting Study. Volume II. Final report, Jul 1975-Jun 1976. (United Engineers and Constructors, Inc., Philadelphia, Pa. (USA)). Jun 1976.

Economic and optimal system evaluation of a nuclear power plant site selection study are presented. Also included is an analysis for determining an optimum mix for the nuclear plant. The evaluation is complex because of many diverse considerations needed to accurately reflect the economics of using a standard nuclear reactor in an existing system with dual requirements of steam and electricity. Also other factors must reflect how the nuclear reactor fits into the overall system.

Total Energy Merseyside Power Station Extension. Energy Dig. (London ; 6: No. 1, 21-23(Feb 1977)).

The Merseyside Power Station on Bromborough Port Industrial Estate is operated by UML Limited, the Unilever services company on Merseyside. Its main feature--particularly significant in these days of world energy shortages and continually increasing fuel prices--is in being a dual energy station which produces both steam and electricity. The station provides steam supplies to some 15 local companies and the electricity requirements of nearly 50. As the load developed in the early 1960s the original four 45 ton/h 45 bar, 450°C boilers and 14 MW of back pressure electrical generation became inadequate to meet the needs, and in 1966 an additional 104 ton/h 103 bar, 538°C boiler and 13MW of electrical capacity were commissioned. By the 1970s it became evident that consideration should again be given to extension of the station as some of the original Central Power Station plant which had been used as standby was nearing the end of its useful life, and the system load was continuing to grow. After consideration of various possibilities it was decided that the requirements could best be met by the provision of a second 104 ton/h boiler and a 5.8MW 102/45 bar back pressure turbogenerator. The new oil-fired boiler, water-treatment system and generating plant are described. Steam and water pipe-work systems are interconnected with the existing station pipework at all pressures from 1.4 bar to 45 bar on steam and 3.4 bar to 141 bar on water. The plant operates at an annual thermal efficiency of 78% and thus also makes valuable contribution to energy conservation.

Andrzejewski, S. Coupled Generation of Heat and Electrical Energy.
Fernwaerme Int.; 5: No. 4, 111-114 (Aug 1976).

The author gives a comparative survey of the papers dealing with this problem on the 3rd international conference on district heating in Warsaw.

Awerbuch, L, T.E. Lindemuth, S.C. May and A.N. Rogers. Geothermal Energy Recovery Process. (Bechtel Corp., San Francisco). Desalination; 19: No. 1/2/3, 325-326(1976).

A novel process for the production of both power and water from geothermal brines is described. The Bechtel process isolates power plant components from the corrosive soluble gases and scale-forming vapors by exposing them only to pure steam, generated by transferring heat from flashed geothermal vapor to distilled water. One of the novel features of this system is the preheating of condensed turbine exhaust in the direct contact recovery unit. The performance of the energy recovery system is discussed for two types of geothermal brine, typical of sites in the Imperial Valley. Several alternatives are compared with the Bechtel process.

Azhari, N. Distillation Plant for the Desalination of Sea Water Combined with a Thermal Power Station. Patent 2,531,295/A/. 20 Jan 1977. p. 9.

During the operation of these combined plants it is difficult to bring in line the energy release with the energy consumption. It is proposed to fit an additional downdraft evaporator to the flash-type evaporator in the distillation plant in order to get an improved utilization of the energy generated in the steam power plant. The pressure side of the steam compressor in the thermal power station is connected with the vapor space of this evaporator on its suction side, and with the fire box on its inlet side. Distillate and hot brine are fed into the first stage of the flash-type evaporator.

Bachl, H. Combination of Thermal Power Processes with a Fuel Conversion Process. Patent 2,527,662/A/. 23 Dec 1976. p. 7.

The gasification of fuels normally occurs at high temperatures and increased pressure. In order to increase the efficiency, it is recommended to carry out the heat production in at least two steps and to interpose the fuel conversion between them. By this means also a higher yield of high-molecular hydrocarbons will be achieved, and one additional separation of the residual gas can be dispensed with. The initial temperatures of the first thermal power process are given as about 900 to 950°C, those of the second as 450 to 550°C. The heat consumption for the fuel conversion will be covered primarily by the first thermal power process and will occur at >10 bars. Further claims contain the possibilities of circuit direction, the use of different heat sources, as well as the utilization of the energy gained.

Baldin, A.M. and I.N. Semenyshkin. Synchrophasotron of the Joint Institute for Nuclear Research and its Development. (Joint Institute for Nuclear Research, Dubna). Sov. J. Plasma Phys. (Engl. Transl.); 3: No. 3, 244-345 (May 1977).

A brief review of the development and accomplishments of the Dubna synchrophasotron is given with emphasis on the acceleration of light nuclei.

Best, F.R., S.B. Goldman and M.W. Golay. Analysis of Nuclear and Coal Fueled Total Energy System Options for Fort Knox, Kentucky. Final technical report, June 1976-June 1977. (Massachusetts Inst. of Tech., Cambridge (USA). Dept of Nuclear Engineering). 30 Jun 1977.

A Total Energy System is designed to supply the thermal and electrical energy requirements of Fort Knox for 30 years, with startup scheduled for early 1985. Considered for use as the central station power plant for this system are a combined coal gasification, fossil-fired gas turbine (CGGT) power plant and a direct Brayton cycle high-temperature gas-cooled reactor, helium gas turbine (HTGR/GT) power plant. Several utility system configurations affording different thermal/electrical energy demand ratios are studied for each supply option. It is found that the optimal thermal/electrical load split for each supply option occurs at approximately 80% of the base's total energy demands supplied thermally. Within the limits of the unit-cost assumptions made and for the range of cases studied, it is found that the present-worth total cost of the optimized HTGR/GT system (in 1985 dollars) is \$234.5 million and the corresponding optimal system cost for the fossil CGGT alternative is \$182.2 million.

Boese, F.K., W. Breyer and R. Pruschek. Cost Comparison of Low-temperature Heat Production and Supply to the Industrial and Domestic Sector by Means of Nuclear Energy. (Gesellschaft Fuer Hochtemperaturreaktor-Technik mbH, Bergisch, Gladbach, Ger.). Nucl. Technol.; 38: No. 2, 304-311 (Apr 1978).

The economics of different nuclear systems to meet the low-temperature heat demand are compared. The comparison concentrates on substitute or synthetic natural gas (SNG) produced from coal and nuclear high-temperature heat. The market potential as well as the economic benefit for the Federal Republic of Germany (FRG) has been assessed under realistic boundary conditions. In spite of the relatively high investment costs, it is expected that SNG can be competitively used in the FRG. If a price escalation rate of natural gas slightly above the general inflation rate is assumed, a large public benefit can be expected.

Butler, P. New Heat and Power Package is Leaping Over the Final Hurdle. Engineer; 245: No. 6339, 59 (22 Sep 1977).

A dual-purpose power plant for the co-generation of electricity and process heat is planned. The plant will use diesel engines, waste heat boilers, and economizers for additional heat recovery to preheat boiler feedwater.

Charroppin, P. Some Thoughts on Optimizing Long-distance Heat Transport Systems and Their Storage Facilities. (Cold Regions Research and Engineering Lab., Hanover, N.H. (USA)). Dec 1976. Translation of Unpublished Manuscript (France) November 1975.

A study of transport of heat produced in nuclear power reactors with a high enough rating to benefit by scale economy and relying on seasonal storage to flatten the production curve is presented. It aims at optimizing such transport systems and is first of all a search for a simple mathematical method for determining immediately the optimal diameters and the corresponding costs.

Chernyaev, V.A., V.V. Rybachev, V.E. Makarov, E.Ya. Solkolov and V.S. Bunin. Comparative Economic Efficiency of Nuclear Heat and Power Plants. Teploenergetika (Moscow); No. 3, 9-13(Mar 1975).

Problems of comparative efficiency of nuclear heat and power plants with different initial steam parameters are considered. Methods of determination of full rated expenditure in such plants, of the district heating coefficient, and of the type of principal equipment are discussed.

Curley, C.C. Martins Creek S.E.S. 800-MW Units 3 and 4: Design and Operating Experience with Axial-flow FD and ID Fans. (Pennsylvania Power and Light Co., Allentown); Overas, A.J. Proc. Am. Power Conf.; 38: 681-693(1976).

The design and performance of the variable-pitch axial-flow forced-draft and induced-draft fans used in two 820MW generating units at the Martins Creek Power Plant are described. Information is included on fan design; silencers; mechanical and metallurgical testing; insulating; performance testing; start-up and shutdown procedures; and maintenance.

Davis, A.A. Heat and Electrical Power Cogeneration Retrofitting Technique. Costs and Benefits. (Argonne National Lab., Ill. (USA)). 1978.

A cost-benefit analysis is made of techniques for retrofitting existing power plants to obtain heat energy for district heating and cooling systems (DHCS). The five generic methodologies for obtaining that heat energy include: condensing pressure and extraction volume increase retrofit on the existing steam turbines;

intermediate crossover extraction retrofit on the existing steam turbines; recuperator boiler retrofit on existing gas turbines; installation of new specially manufactured variable extractions steam turbines; and conversion of existing steam boilers in hot water boilers. Each of the above options was reviewed to ascertain the effects on the existing utility systems. It was established that the use of a 100% cogeneration in a DHCS system is not economical, and 10 to 40% of the heat energy should be provided in a pure heat production. It appears that the future development of the DHCS will require more heat energy than can be provided by the new electric generating units which will work in cogeneration, and it is clear that the involvement of the existing units will be done by retrofitting them with reasonable costs and not replacing them with new units.

Decker, G.L. Power Plant Design Considerations for Energy Conservation. (Dow Chemical Co., Midland, MI). pp. 95-100 of In Energy use management. Vol. I. Frazzolare, R.A. (ed.). Elmsford, NY; Pergamon Press Inc. (1977).

The energy conservation potential of co-generating steam and electric power by either generating by-product electric power in process steam-producing industrial plants or by producing by-product steam in thermal or dual-purpose power plants is discussed. It is concluded that the joint generation of industrial process steam and electric power offers distinct advantages in terms of lower fuel consumption, lower transmission losses, and less capital investment.

Dietzel, F. Boiler Operation and Combined Heat and Power Generation. Betriebstechnik; 17: No. 1, 28, 33-34(1976).

Due to the primary energy saved, combined heat and power generation is of great economic importance. At the same time, environmental pollution is reduced due to the smaller amounts of waste gas and condensation heat. In this process, the production and/or heating steam generated in a steam boiler is led into a steam turbine for electric power generation via waste heat boilers or by compression. The process is described.

Dittrich, R.F. and K.D. Allon. PSE and G Cogeneration Evaluation. (Public Service Electric and Gas Co., Newark, N.J. (USA)). Jan 1977. p. 46.

In order to foster all possible methods of conserving energy within New Jersey and to provide the lowest possible energy costs to its customers, Public Service Electric and Gas Company (PSE and G) investigated the potential for cogeneration within the PSE and G electrical territory. Cogeneration is defined in this report as the production of industrial process steam as a by-product of electric generation located at the industrial plant. The cogeneration evaluation uses a "total system" in which the total costs of

PSE and G and the customer are determined. Two scenarios were compared: PSE and G system expansion based on the potential cogeneration displacing planned nuclear units, and the presently planned PSE and G system expansion. "Site specific" studies were evaluated for the 18 PSE and G customers with a minimum steam usage of 50,000 lbs/hr for 5000 hrs or more who were the best prospects for cogeneration. This study concluded that: cogeneration is a theoretical alternative for 18 customers in the PSE and G electric territory with a total potential of about 430 MW of generating capacity; cogeneration is not an economic alternate to nuclear capacity, involving a present worth penalty of \$400 million for 430 MW; of the 18 customers, 12 totaling 300 MW may have the potential by a very small margin for providing cogeneration as an economic electric capacity addition on the PSE and G system; and cogeneration would significantly increase America's dependence on oil which is currently counter to national policy.

Elmenius, L. By-product Power: The Energy Conservation Way. (Stal-Laval Turbin AB, Finspong, Sweden); McConnell, J.E. Proc., Am. Pet. Inst., Sect. 3;55: 329-341(1976).

Energy conservation necessitates new examination of industrial applications requiring both process heat and electrical energy. Past applications approaches during times of lower cost energy and financing are not appropriate today. With increased costs of materials, capital, fuel and power, new techniques are required which better permit maximizing efficient power generation. Today's application engineering is looking for better results and faster pay-offs through savings in energy and reductions in capital costs. The principle of energy flow in a by-product power plant, the build-up of a duration curve and its usefulness for evaluation of various application parameters are outlined. An example from a field installation is provided as an illustration that maximizing by-product energy also improves the return on investment. Alternative solutions are described in terms of energy units since energy units can be readily capitalized for each individual case.

El-Nashar, A.M. Engineering Aspects of a Dual-purpose Electrical Power Generating Hyperfiltration Desalting Plant for Middletown, Arabia. (Univ. of Mansoura, Egypt); Husseiny, A.A. Desalination; 19: No. 1/2/3/, 189-199(Dec 1976).

The design of a dual-purpose plant that consists of a fossil-fueled power station and a reverse osmosis (hyperfiltration) desalting unit is considered. The plant is to be sited on the seacoast near Middletown, Arabia. This is a hypothetical metropolitan area which represents an average town in the region of the Mediterranean, Red Sea, Indian Ocean, or the Arabian Gulf. The reference town has a typical population density and electricity and water consumption patterns of cities presently located in the region of interest. The sale of electrical energy is assumed to be fixed by the utility companies and/or the government regulations. The design of the plant will be optimized to produce water at the lowest possible cost. Membranes with intrinsic rejections of 70 percent to 97

percent are considered. The optimum membrane permeability, operating pressure, water recovery and storage capacity are obtained.

Elter, C., E. Haugh and H. Morassi. Effects of a Pipe Rupture Accident on the Reactor Internals in a Boiling Water Reactor Demonstrated by the Example of Philippsburg. (Technische Ueberwachungsverein Baden, Mannheim, Ger.). Nucl. Technol.; 37: No. 3, 204-226(Mar 1978).

In the course of the evaluation of the Philippsburg I boiling water reactor in the Federal Republic of Germany, carried out for the licensing authorities, the behavior of the reactor internals during a pipebreak accident was analyzed by theoretical calculations. During this accident, the reactor internals are exposed to a short-time negative pressure wave that expands in the water and is rapidly attenuated. The extent of the influence this load has on the operating capability of the components, particularly of the shut-down facilities, was analyzed. Linearly elastic dynamic analyses were carried out on the mechanical behavior of the structure on the basis of calculations of the time- and space-dependent pressure distribution on the core shroud and vessel dome. Staggered geometries and attenuation were not taken into consideration. All calculated components were treated as axially symmetric structures. The load is not axially symmetric and is therefore represented as a Fourier series. The results are given in the form of stresses, displacements, and forces as a function of time.

Erdoedy, L. and K. Kuenstle. Sea Water Desalination and Steam Generation With Nuclear Energy. A Comparison and Study of Two Possible Circuits of a Compound System with Pass-out Condensation or Back-pressure Turbine. (Kraftwerk Union A.G., Erlangen (F.R. Germany)). pp. 837-840 of In Reactor Conference, Duesseldorf, 30.3-2.4. 1976. Section 4: Reactor concepts and economics. Eggenstein-Leopoldshafen, F.R. Germany; ZAED (1976).

Two flow diagrams for compound systems with pass-out condensation and back-pressure turbines are compared and analyzed.

Foerster, S., G. Hewing and B. Sack. Energy System with Nuclear Power Stations for the Generation of Public Current and of Hydrogen from the Electrolysis of Water. 29: No. 2, 59-65(Feb 1977).

The article describes a large system for the generation of public current and of hydrogen from the electrolysis of water, based on nuclear power stations. Full-load operation of the nuclear power stations and intermediate storage of the hydrogen produced are essential for the operation of the system. Starting with an estimation of the power stations output to be installed in a system for the Federal Republic of Germany in the year 2,000, the method of constructing the system from basic units is described. The outstanding specific characteristics, such as method of operation, safety, energy conversion and economics, are shown for nuclear

power stations of the presently operating and advanced designs, as well as for electrolysis techniques tested today. The storage of hydrogen is also included. The possibilities of realizing the system and of a representative demonstration plant are outlined.

Gneuss, G. Combined Heat and Power Generation in a Brewery. Energie; 29: No. 5, 143-145(May 1977).

A brewery in Southern Germany is used as an example to demonstrate the close connection between increased and rationalized production and the exploitation of all ways and means of more efficient energy consumption. Installing a uniform pressurized steam system for all steam consumers, meaningful harmonization of the operating periods of the individual steam consumption centers, and reduction of the expensive peak load supplies from the public grid helped to decrease production costs by means of a reduction in energy costs. The heat power plants, which are now operated in an evenly balanced load regime, are now even able to deliver excess electricity into the grid. When the production and power plants had to be enlarged even further, a decision had to be taken either in favor of a turbine or a high speed steam engine system. The decision was taken in favor of the steam engine because of its higher efficiency, i.e., better utilization of the steam, and also for the capability of the steam engine system to be operated in a fully automated pushbutton mode. The primary energy requirement of the plant electricity generation system is now only half the requirement of public condensation power plants on a kilowatt-hour basis. In this way, energy consciousness in heat-consuming industries helps to achieve more efficient energy consumption.

Green, L. Jr. Gas-turbine Total Energy System for a Cement Plant. New York; American Society of Mechanical Engineers (1977). p. 6.

The use of coal-fired closed-cycle gas turbine to provide electric power and process heat to a "wet process" cement plant is proposed. Taking the example of a large plant requiring 100 million kilowatt-hours of electric energy per year, it is estimated that, by substitution of implant power generation for purchased electricity and use of reject heat for slurry dewatering, annual energy cost savings (at current rates) sufficient to pay off the capital cost of the installation between 5 and 15 years (depending upon the amount of that cost) could be realized. This degree of savings will increase as the price of power increases due to "normal" projected escalation of coal costs, plus the imposition of requirements for emission control equipment to meet stringent environmental quality standards. Because the fly ash from pulverized coal firing and the limestone sludge from a stack-gas scrubber represent feed materials for the cement process, emission control does not constitute the burden on a cement plant that it would for an electric utility, but rather permits additional savings due to effective use of "waste" materials. Conservation of energy, material resources, and the environment could thus be accomplished simultaneously.

Greil', A.D. and A.M. Sakharov. Results of Thermal Tests of the Prototype of the Type T-250/322-240 Turbine Set Made by the Urals Turbomachinery Plant. (ORGRES, USSR). Teploenergetika (Moscow); No. 2, 2-6(Feb 1977).

Principal results of the T-260/300-240 turbine set tests are presented. This is a four-cylinder single-shaft turbine with the rated steam parameters of 24.5 MPa (240 kg/cm²) and 540/540°C. It has 10 steam takeoffs for regeneration and for a feedwater turbopump, including a controlled takeoff for district heating up to 384 MW (330 Gcal/h). The test results given in tables show that the manufacturer's guarantees have been kept, without counting tolerance, with an average underconsumption in district heating modes by 2.5%. However, owing to poor seals and other losses, the efficiency of the turbine is found to be somewhat lower than expected.

Head, M.A. Intermediate Size LWR Plant Study for Process Heat Plus Power: Main Report. Volume 2 of 3 volumes. (General Electric Co., San Jose, Calif. (USA)). Jan 1977.

The study of process heat-plus-power generation from 900 to 1200 Mwt BWRs was initiated by analysis of the smaller BWR plants, which have substantial operating experience. The Muhleberg 306 MWe BWR (four years of operation and 74% capacity factor) and the Humboldt Bay, natural circulation system (ten years of operation and 69% capacity factor) were identified as leading plants. The Muhleberg design, cost, and operating data, therefore, were analyzed in further detail. Analysis was also conducted on the Humboldt Bay unit, even though its 63 MWe size is not directly applicable. In this case, attention was focused on the potential for updating the natural circulation concept to the 1000 Mwt level. Cost analyses were conducted on actual costs incurred, including correction indices for escalation to 1976. The changes in licensing requirements were evaluated and their cost impact estimated. Some indication of the economics possible through standardization and use of modular construction were estimated by reference to earlier work under the nuclear park (or energy center) study program. Consideration was directed to the organizational needs for design, construction, and project management, if an effective program were to be undertaken. The importance of a demonstration project as a means of establishing a design standard for duplication or replication (and the program requirements to being about such a demonstration project) were then addressed. Finally, capital costs developed from the actual plant costs were used to determine power generation costs.

Hilsen, N.B. (Georgia Inst. of Tech., Atlanta), G.R. Fletcher, R.D. Wilkins, J.S. Tiller and C.C. Lee. Environmental, Economic, and Conservation Aspects of Integrated Energy Systems. pp. 621-628 of In Proceedings of the 12th Intersociety Energy Conversion Engineering Conference. Vol. I. La Grange Park, IL: American Nuclear Society, Inc. (1977).

An Integrated Energy System (IES), in which utility power plants supply both electrical and steam needs to one or more nearby industries, results in increased energy efficiency, reduced pollutants, and reduced overall cost. In order to assess the potential for IES development, an environmental, economic, energy efficiency and social impact analysis is conducted. Differences between the Status Quo approach to providing steam and electric power to industries is compared with the IES approach through a Cost-Benefit Analysis. Several IES concepts are analyzed using the techniques described. A rationale for the IES, a methodology for analyzing IES concepts, and results of an analysis for one specific concept are presented.

Hornburg, C.D. and J.E. Cruver. Dual Purpose Power/water Plants Utilizing Both Distillation and Reverse Osmosis. Desalination; 20: No. 1/2/3, 27-42 (Mar 1977).

The energy consumption of several alternate dual purpose plants are compared for application in the range of 10 to 50 MW with 1 to 20 MGD water production. This shows that the combined gas turbine-steam turbine system is considerably more energy efficient than a steam-only system. Single state reverse osmosis (RO), used in conjunction with this combined cycle, offers the minimum overall energy consumption but has the disadvantage of producing product water with high TDS. By utilizing both RO and distillation, energy consumption lower than with distillation alone is achieved and product water purity is acceptable. A specific design of a combined dual purpose plant is presented. This plant would have a net electrical output of 29,050 kw and 3.25 MGD of 440 ppM TDS, requiring 297.1 BTU/hr. The total capital costs of this combined plant is estimated at \$41,150,000 and annual operating costs at \$15,087,000. The unit production costs with fuel at \$2.50/MM BTU would be 4.08 cents/kw-hr and \$2.44 per 1000 gal. This represents an annual savings of \$1,961,000 over single purpose production or 44.5% reduction in water production costs with the same electrical production costs. It is concluded that the combined dual purpose plant presented is the most efficient, economical and flexible method of producing power and water in the range of 10 to 50 MW and 1 to 20 MGD.

Izaki, T., T. Iino, Y. Tanaka and Y. Matsuki. Design of a Large-scale, Multi-purpose High Temperature Gas-cooled Reactor System. Kawasaki Heavy Industries Ltd., Kobe (Japan)); Matsuda, M. FAPIG (Tokyo); No. 72, 225-247(Feb 1974).

The trial design of a large-scale, multi-purpose high temperature gas-cooled reactor system is described on its three aspects: nuclear reactor, nuclear heat utilization, and safety. The system is a littoral iron- and steel-making plant employing a multi-purpose HTGR (heat output 3000 MW) with helium gas temperature of 1000°C; the capacity is about 6,300,000 tons of crude steel production per year. It consists of a direct reduction furnace for ore and an electric furnace, and also an electric power generating facility.

Jones, D.W. Mobile Nuclear Power Plants: Initial Feasibility Study. Research Report. (Memphis State Univ., Tenn. (USA). Center for Nuclear Studies). May 1976. p. 39.

This study addresses an alternate method for the utilization of nuclear energy which could satisfy industrial energy needs in areas of our nation where primary fuels and other energy resources are not available and which could provide energy for the development of American industry abroad. This alternative is cost competitive with oil and some forms of coal and will provide both steam and electrical power at industrial plant sites. Both technical and economic feasibilities of this energy resource are described, and a program is outlined for its development. Recommendations are also made that a demonstration project be started to establish the feasibility of this alternative.

Karkheck, J. and J. Powell. Prospects for the Utilization of Waste Heat in Large Scale District Heating Systems. (Brookhaven National Lab., Upton, N.Y. (USA)). 1977.

District heating is one potential application for power plant reject heat. In addition to reduction in plant thermal pollution, it offers the potential to conserve over one billion barrels of oil per year. Detailed analyses of model district heating systems for nine U.S. urban areas, including projected heat costs, are presented. In addition, projections of nationwide levels of implementation of district heating systems are discussed. Results show that about half of the current population could be served through district heating at heat cost levels equal to the effective heat cost of imported oil.

Karkheck, J., E. Beardsworth and J. Powell, Technical and Economic Aspects of Potential U.S. District Heating Systems. (Brookhaven National Lab., Upton, N.Y. (USA)). Apr 1976.

District heating stands as a means to conserve fossil fuel through more efficient utilization of these resources as a primary source of heat because it can supplant the application of fossil fuels to a great extent by utilizing waste heat from various sources. Of paramount interest as a source of waste heat are the steam electric generating plants, especially those powered by nuclear fission. Utilization of this by-product allows immediate cutback in fossil fuel consumption. It relieves the environment from bearing the burden of huge amounts of excess heat. It opens the supply of fossil fuels to more complex applications where these are used to greater advantage. It raises the energy conversion efficiency of these electric plants considerably and is economical. Following the Introduction, Section II presents an analysis of a study of nine urban regions that collectively display a wide variation in the parameters that are the primary determinants of unit heat cost. These regions are New York City, Chicago, Philadelphia, Los Angeles, Baton Rouge, New Orleans, Jersey City, Newark, and Paterson. They show great variety in climate, size, population and population density, housing profile, working conditions, and labor costs. The goal of the analysis is to project heat demand in each region, design appropriate hot water piping systems to distribute this heat, and compute unit heat costs based on district heating system capital and operations costs and yearly heat demand. Section III presents a generalization of this analysis. Section IV discusses various technical and economic aspects of the adaptation of electric plants to a dual role as heat-electric energy sources. Section V contains the concluding remarks.

Kawasa, O. Utilization of Multi-purpose High Temperature Gas-cooled Reactors. Electric Power Generation with Gas Turbines. (Fuji Electric Co. Ltd., Yokosuka, Kanagawa 9Japan). Central Research Lab.); Onuki, Y. and T. Wasaoka. FAPIG (Tokyo); No. 72, 275-280 (Feb 1974).

Concerning the utilization of multi-purpose high temperature gas-cooled reactors, the electric power generation with gas turbines is described: features of HTR-He gas turbine power plants; the state of development of He gas turbines; and combined cycle with gas turbines and steam turbines. The features of gas turbines concern heat dissipation into the environment and the mode of load operation. Outstanding work in the development of He gas turbines is that in Hochttemperatur Helium-Turbine Project in West Germany. The power generation with combined gas turbines and steam turbines appears to be superior to that with gas turbines alone.

Klepper, O.H. Nuclear Dual-purpose for Industrial Energy. (Oak Ridge National Lab., TN). pp. 1065-1072 of In Eleventh inter-society energy conversion engineering conference. Vol. II. New York; American Institute of Chemical Engineers (1976).

One of the major obstacles to extensive application of nuclear power to industrial heat is the difference between the relatively small energy requirements of individual industrial plants and the large thermal capacity of current power reactors. A practical way of overcoming this obstacle would be to operate a centrally-located dual-purpose power plant that would furnish process steam to a cluster of industrial plants, in addition to generating electrical power. The study presented indicates that even relatively remote industrial plants could be served by the power plant, since it might be possible to convey steam economically as much as ten miles or more. A survey of five major industries indicates a major potential market for industrial steam from large nuclear power stations.

Korneichev, A.I., I.V. Dmitriev and M.O. Fridman. Universal Criterion for Optimizing Versions of Heat Supply from Heat and Power Stations. Therm. Eng. (USSR) (Engl. Transl.); 23: No. 4, 38-41(1976).

In the engineering and economic optimization of a heat and power station using the method of completing expenditures on electric power, as with use of conventional methods of comparison, a universal criterion of estimation is the difference between design expenditures for the appropriate version of the station and the expenditures on power supply in a separate system equivalent to this version. An equation is given to determine the expenditure on power supply in the separate system. If the station is characterized by different thermal loads, then, in the equivalent separate system, one should make allowance for full expenditures on energy supply. The proposed criterion can be used both in automation of the calculation process and in manual calculations. The use of this criterion in developing algorithms of engineering and economic calculations, using electronic computers, simplifies the algorithm and reduces the volume of programs and machine time.

Korytnikov, V.P., M.V. Mirovskii, V.I. Gorin and V.F. Kalinov. Performance of Heat-and-power Plants with Equipment for the Pressure of 130 kgf/cm² and Some Ways to Save Fuel. (Minenergo SSR, USSR). Teploenergetika (Moscow); No. 12, 48-52 (Dec 1977).

The technical and economic level of operation of heat-and-power plants (HPP) and their analysis in comparison with unit plants is presented. It is shown that technical performance of 93 Soviet HPP for the pressure of 130 kgf/cm² with respect to many indices is, practically speaking, close to the level of unit steam power plants and with respect to the efficiency of energy production and thermal efficiency somewhat higher. The total technical reserve of fuel economy at these HPP amounts approximately to 9-10 Mtec.

Kovacik, J.M. Impact of Higher Energy Costs on Turbine System Selection for Industry. (General Electric Co., Schenectady, NY). Proc. Am. Power Conf.; 39: 765-773(1977).

Industrial plants which require both process heat and electric power should evaluate plant energy supply systems to determine whether turbines, providing electric and/or shaft power, can improve their effective use of energy. The economic and energy considerations in such an evaluation are discussed. It is concluded that with rapidly rising fuel costs, in-plant power generation for industries requiring large quantities of process heat should continue to conserve energy resources and reduce product costs.

Kovacik, J.M. Industrial-utility Colocation for Integrated Process Heat and Power. (General Electric Co., Schenectady, NY). Proc. Am. Power Conf.; 38: 803-812(1976).

Results are presented of a study which examined the economic merit of colocating industrial plants adjacent to fossil-fuel or nuclear power plants so that the utility power plants could provide both electric power and process heat to the industrial plants. This study shows that economics continue to favor industrial generation of steam and power (kW and/or hp) for those industries having large demands for process steam at pressures of 200 psig or less. However, colocation with nuclear-fueled utility plants might prove economic for those industries having steam demands at pressures in the 250 to 600 psig range. The economics, in this instance, are significantly influenced by the low cost of nuclear fuel relative to fossil fuels. Although the scope of this evaluation was limited to the tangible investment and operating cost considerations of colocation, there are many other factors requiring detailed study. Some of these include the additional environmental aspects of colocation, the influence of siting on the production and distribution costs of the goods produced, the probability of industrial process obsolescence and its impact on the economics of colocation, industrial growth and land-use policy, etc.

Krebs, F. Water and Power Installation for Lanzarote (Canary Islands) Spain. (Babcock and Wilcox, Espanola SA, Madrid). Desalination; 20: No. 1/2/3, 173-191(Mar 1977).

Water-producing and electrical-generating facilities had to be increased on the Spanish Canary Island of Lanzarote for it to develop beyond its 1972 status. The Ministry of Public Works prepared specifications for a turnkey installation of two 2500 M³/D desalting plants and a 5 MW (net) generating system. In 1973, through international competition, Babcock and Wilcox, Espanola won a contract to build the installation. In December 1975 the construction of the project was completed. In early January 1976 the

first line was producing 103% of the rated production at a thermal efficiency of 120% of the rated value. The second line was modified to operate at a reduced maximum brine temperature and commissioned. This plant was brought to full production which was 115% of the rated production in 2 1/2 days. Problems and delays during the commissioning, were minimal. A 5-day performance test of the installation was run. During this test the water production was 111 1/2% of the rated value at a specific energy consumption of 93% of the rated value while the maximum brine temperature was maintained 6°C less than the design value. The high performances were achieved because the plants were well designed and built and properly commissioned. During the first 4 1/2 months that the owner operated the installation it provided water and power as demanded. During that time the average plant production was 107% of the rated capacity.

Kunst, B. Evaluation of Secondary Energy in the Case of Power-Heat Coupling. (Fachhochschule Koeln (Germany, F.R.). Fachbereich Versorgungstechnik); Hapke, J. (Thyssen Energie G.m.b.H., Essen (Germany, F.R.)). VIK (Ver. Ind. Kraftwirtsch.) Mitt.; No. 3, 38-46 (Jun 1977).

Power-heat coupling, in view of steeply risen fuel prices since 1974 and also in view of energy conservation efforts by all industrial enterprises using electric power and process steam, can gain in importance only if considerations concerning the various methods for apportionment of steam generation costs onto individual consumers come to the fore again. The authors of this contribution analyze on the basis of a simplified model of the supply system the possible methods of cost allocation. They find that, in a thermodynamic sense, only those methods are justified that take the energy content of the steam into account. However, in the end, neither the pure energy method nor the arithmetic averaging of heat and energy can stand up to an examination; nothing but the geometric average determination fulfills all thermodynamic and managerial economic-related requirements. 7 figs, 3 tables, 11 references.

Lavrenenko, K.D., L.A. Melent'ev, L.S. Popyrin and V.V. Gapeev. Promising Types of Principal Power Plant Equipment. (Acad of Sci of the USSR). Teploenergetika (Moscow); No. 9, 2-5 (Sep 1977).

Some criticism of the existing power plant construction policy in the USSR is followed by a statement of desirable policies. In particular, it is argued that in the European part of the USSR there should be no limit on the concentration of equipment, i.e., units with unit capacity of 2-3 million kW should be built there. There should be restrictions on the fuel used. New basic condensing power plants fired by nuclear fuel and coal should be rapidly built. Long-term requirements in maneuverable semi-peak and peak equipment should not be underestimated and should be made more precise. The use of nuclear power plants for combined heat and power production and development of a type of fast neutron reactor within 10 years is urged. Research on the feasibility of underground pumped storage hydroelectric power plants is proposed.

LeMartret, J.P. Desalination Through the Vapour Compression Process in Large Plants. (Societe Internationale de Dessalement, Paris). Desalination; 19: No. 1/2/3, 337-348(1976).

The vapor compression process for desalination by evaporation shows great advantages over classical processes like multistage flash.

Leprince-Ringuet, L. Nuclear Energy and Water Desalination. (Ecole Polytechnique, Paris). pp. 33-44 of In Biological and artificial membranes and desalination of water. Passino, R. (ed.). Vatican City; Pontifica Academia Scientiarvm (1976).

Brief descriptions of procedures for desalination of sea or brackish waters are presented. The potential for dual-purpose nuclear plants for electricity production and desalination is discussed.

Loh, W.P. Simultaneous Load Analysis of an Electricity and District-heating Supply System. (Wibera, Duesseldorf, Ger). Fernwaerme Int.; 6: No. 1, 1-4(Mar 1977).

The analysis of the time behavior of the power requirement for system input (also called load) is the basis of many studies made by supply undertakings for planning purposes. The planner wishes to know how frequently the cases of loading occur. As an aid in characterizing the time of utilization of supply plant, duration curves are often used. On this basis a computer-based form of presentation is developed for two-dimensional load variations, as they occur in power stations, heat-electric stations and heating stations working in combination for electricity and district-heating supply. By using this method comprehensive loading data can be converted into an understandable form which is suitable for further investigation.

Maier, K.H. Technical and Economic Aspects of Industrial Combined Heat and Power Generation. Pt. 2. Energie; 29: No. 8, 255-258(Aug 1977).

This follow-up article to the article from ENERGIE vol. 29, 5/1977, gives a check list to help those who are not acquainted with the work of the electric power industry. The check list indicates whether district heat, self-produced power, or power supplied by utilities is cheapest.

McConnell, J.E. Systematic Approach to the Economic Selection of Design Parameters for an Integrated Industrial Power Plant. (ASEA Inc., White Plains, NY); Elmenius, L. Proc. Am. Power Conf.; 38: 793-802(1976).

A rational basis for examining the performance of an integrated industrial power plant, i.e., a plant which supplies both electric energy demands and process heat demands is presented. From this

examination it is concluded that integrated power plants which provide both electrical and thermal process energy can be optimized to improve byproduct electrical energy gains while at the same time minimizing capital outlays for the turbine cycle, thus conserving available capital for improved utilization of available waste fuels and lower-grade fossil fuels. Emphasis on utilizing byproduct energy and lower-grade fuels will benefit the national interest by overall improvement of energy utilization practices.

McMain, A.T. Jr. Energy Alternative for Industry: The High-temperature Gas-cooled Reactor Steamer. (General Atomic Co., San Diego, CA); Blok, F.J. Nucl. Technol.; 38: No. 2, 271-279(Apr 1978).

Large industrial complexes are faced with new requirements that will lead to a transition from such fluid fuels as natural gas and oil to such solid fuels as coal and uranium for supply of industrial energy. Power plants using these latter fuels will be of moderate size, 800 to 1200 MW (thermal), and will generally have the capability of regenerating electric power and process steam. A study has been made regarding use of the 840-MW(thermal) Fort St. Vrain high-temperature gas-cooled reactor (HTGR) design for industrial applications. The initial conceptual design (referred to as the HTGR steamer) is substantially simplified relative to Fort St. Vrain in that outlet helium and steam temperatures are lower and the reheat action is deleted from the steam generators. The Steamer has four independent steam generating loops producing a total of 277 kg/s ($.2 \times 10^6$ lb/h) of prime steam at 4.5 MPa/672 K (650 psia/750 $\frac{1}{2}$ F). The unit cogenerates 46 MW (electric) and provides process steam 8.31 MPa/762 K(1200 psia/912 $\frac{1}{2}$ F). The basic configuration and such of the equipment are retained from the Fort St. Vrain design. The system has inherent safety features important for industrial applications. These and other features indicate that the HTGR Steamer is an industrial energy option deserving additional evaluation. Subsequent work will focus on parallel design optimization and application studies.

Metcalfe, L.J. and M.J. Driscoll. Economic Assessment of Nuclear and Fossil-fired Energy Systems for DOD Installations. Final report. (Massachusetts Inst. of Tech., Cambridge (USA). Dept. of Nuclear Engineering). Feb 1975.

Costs of electricity and thermal energy (380 F hot water) produced by nuclear and fossil-fired power plants in the 100 MWe size range for 1985 start-up have been estimated (in 1985 dollars, levelized over plant life). While the PWR/Rankine system was estimated to produce electricity as a sole product cheaper than an HTGR/Brayton plant (30.3 versus 41.5 mills/kWhr) the HTGR unit was shown to produce Total Energy products more economically than the PWR (25.2 mills/kWhn and 2.58 \$/MBTU versus 30.3 and 2.93). Breakeven fuel costs for comparable fossil-fired steam-electric power plants were found to be about 16 \$/ton for coal and 4 \$/bbl for oil (approximately 10 \$/ton and 6 \$/bbl in 1974 dollars); oil-fired gas turbine

units were found to have breakeven costs of 18 \$/bbl (approximately 10.6 \$/bbl in 1974 dollars). Parametric and sensitivity studies were also carried out to examine the affects of size (50-200MWe), annual cost of money (8 - 12%), plant lifetime (20-40 years) and plant start-up date (1980-1990). It is concluded that the HTGR/Brayton plant is superior to the other nuclear and fossil/Rankine options for Total Energy applications. The fossil-fired gas turbine/total energy system is identified as a strong competitor for the proposed application, and is potentially superior to the HTGR if fossil fuel prices do not escalate prohibitively.

Nida, A.V. and G.S. Stewart. Dual Purpose Nuclear Power Plants for Military Installations. (Army Facilities Engineering Support Agency, Fort Belvoir, Va. (USA)). 1976. p. 14.

The authors have found evidence that the nuclear total energy system is technically feasible and capable of economically serving the utility needs of military installations. The recovery of thermal energy from a direct-cycle high-temperature gas-cooled reactor would result in significant reductions in thermal emissions and air pollution and aid in the conservation of fossil-fuel resources. Provision of electricity and thermal energy from a nuclear energy center should be considered for total energy systems in appropriately sized urban communities. This concept will accrue the greatest benefits in areas where air quality degradation is to be kept to a minimum and where dependable fuel supply must be guaranteed.

Pffenninger, H. Thermal Power Station Combined with a Plant for Seawater Desalination. (to BBC Brown, Boveri and Company Ltd.). US Patent 4,094,747. 13 Jun 1978.

A combined thermal power station and a desalination plant for seawater are described in which the power station includes a gas turbine set, a waste heat boiler connected to the exhaust gas outlet of the gas turbine and a steam turbine. The waste heat boiler includes first and second sections arranged in cascade on the water side in the flow path of the turbine exhaust gases, the first section in the exhaust gas flow path constituting a steam in the exhaust gas flow path constituting a steam generator for the steam turbine and the second section constituting a source of heat utilized in the desalination plant. Seawater may be passed directly through the second section of the waste heat boiler or high-temperature hot water produced by the second section may be passed through a heat exchanger incorporated in the flow path of the sea water. The waste heat boiler may further include an additional source of heat in the form of a fuel burner for maintaining operation of the steam turbine and desalination plant under emergency conditions in the event the gas turbine set is stopped.

Pluer, R. Design and Experience in the Operation of the Danziger Strasse Gas- and Oil-fired Thermal Power Plant of the Oberhausen Power Supply Company. (Energieversorgung Oberhausen, Ger). VGB Kraftwerkstech.; 57: No. 8, 519-526(Aug 1977).

The thermal power station I of the Oberhausen Power Supply Company dates from 1899 and since 1960 has been supplying an essential part of the heating requirements of the city of Oberhausen through a district power/heating system by means of an associated gas turbine. In 1970 the thermal power station was enlarged by the addition of a back-pressure turbine and now supplies the bulk of the city's district heating requirements, as a result of which only during certain very infrequent peak periods is it necessary to generate fresh heat.

Piir, A.E. and V.B. Kuntysch. Efficiency of Production of Heat and Electric Power at Heat-and-power Central Stations. (Arkhangel'sk Forest Ind Inst im. V.V. Kuibyshev, USSR). Izv. Vyssh. Uchebn. Zaved., Energ.; No. 10, 129-133(Oct 1976).

The cycle of a distinct heating plant is considered as a combination of the direct cycle in which electric power production takes place, and of the reverse cycle of a heat pump, in which production of heat takes place. Starting from the 1st and 2nd principles of thermodynamics, it is shown that heat consumptions for the production of electric power by the condensing and district heating steam flows are similar, and that fuel economy at a heat-and-power central station is achieved as a result of a reversible transformation of heat, applied to the working medium, into low-potential heat required by the heat consumer.

Ivanov, V.A. Thermodynamic Analysis of the Work of Heat-and-power Turbine Plants with Sliding Initial Steam Pressure. (Leningrad Polytech Inst im. M.I. Kahmin, USSR). Izv. Vyssh. Uchebn. Zaved., Energ.; No. 10, 61-66(Oct 1976).

A Thermodynamic analysis of the operation of heat-and-power turbine plants without and with intermediate steam superheating, subject to a combined control program (constant pressure at high flowrates and sliding one at low flowrates), is presented. It is shown that the entire gain for plants without intermediate superheating is attained only with condensing steam flow. The turbine plants with intermediate superheating show a thermodynamic gain both with condensing and district heating steam flows.

Reed, S.A. and J.V. Wilson Desalting Sea Water and Brackish Waters: A Cost Update. (Oak Ridge National Lab., Tenn. (USA)). 20 Oct 1977.

This report, based on first-quarter 1977 dollars, is an update of costs presented in ORNL/TM-5070 (Rev.), which gave cost estimates for desalting seawater and brackish waters based on first-quarter 1975 financial parameters. Cost estimates are given for desalting seawater by distillation and reverse osmosis and for brackish waters using reverse osmosis and electrodialysis. Cost data were computed as a function of plant size and energy cost. The cost of generating steam and electrical energy on-site using coal-fired boilers as well as oil-fired boilers and dual-purpose electric/seawater distillation plants is included. While the costs of energy, equipment and labor have continued to rise, they have increased at a relatively modest rate compared with the two years prior to 1975. On an average, the cost of desalting seawater by distillation has increased approximately 15%. Costs for desalting brackish waters by the membrane processes have increased about 7%.

Riedlinger, R.A. Which Types of Power Stations Can Be Employed for District Heating Supply. (Stadtwerke Duesseldorf A.G. (Germany, F.R.)). Fernwaerme Int.; 6: No. 3, 96-100(1977).

Heat-electric stations functioning as district-heating generation installations are in competition with single domestic fires and heating stations. The author examines gas-turbine heat-electric stations and coal-fired steam heat-electric stations, with back-pressure turbines and with bleeder-type condensation turbines, including the costs of providing back-up power depending on renumeration for the electrical energy. He enumerates the resulting fields of use. On the basis of the build-up of the district-heating supply system with time he explains the most appropriate layout of a heat-electric station.

Robozhev, A.V. Noise Characteristics of Reducing and Cooling Installations. (Moscow Power Eng Inst, USSR). Teploenergetika (Moscow); No. 10, 52-56(Oct 1976).

Some data on natural-size tests of reduction and cooling installations at two heat-and-power plants are presented. Noise measurements were made with loads between 10 and 100%. The experimental data show that the noise level generated by the reducing and cooling installations is very high, exceeding permissible health standards. Some recommendations on reducing the noise level are given.

Saiy, M. Simultaneous Generation of Heat and Electricity. (Arya-Mehr Univ. of Tech., Teheran). 1976.

In Solar cooling and heating: a national forum.

Salminen, P. Some Technical and Economical Aspects of the Nuclear Heat Power Plant and the Heat Transport System. (Valtion Teknillinen Tutkimuskeskus, Otaniemi (Finland). Saehkoetknillen Lab). Dec 1976.

Starting from the estimated development of the electricity and heat demand in Finland until the year 2000, economic aspects of the application of nuclear energy in nuclear thermal power plants instead of conventional energy carriers (already used in Finland) are investigated. The essential factor in it is the distance of heat transmission.

Schatta, M. Weather-power Station. Solar Energy, Wind Energy, Water Energy. German(FRG) Patent 2,412,908A/. 2 Oct 1975. p. 17.

A combined power station is described which enables one to convert solar energy and wind energy into other forms of energy. The plant consists of a water-filled boiler, in which solar energy heats the water by concentration, solar cells, and finally wind rotors, which transform wind energy into electrical energy. The transformed energy is partly available as steam heat, partly as mechanical or electrical energy. The plant can be used for supplying heating systems or electrolysis equipment. Finally, by incorporating suitable motors, a mobile version of the system can be produced.

Schenk, P. Integration of the Heat-electric Economy into the Electricity Supply Economy. (Stadtwerke Duesseldorf A.G. (Germany, F.R.)). Fernwaerme Int.; 6: No. 3, 58-60(1977).

The German electricity supply industry has so far offered considerable possibilities of development of district-heating supply by means of heat-electric stations, when compared with other supply undertakings (mostly nationalized). For a number of reasons they will increase this trend. Numerous district-heating supply organizations are even today supplied economically by heatelectric stations near the point of consumption. A further development of the principles and methods adopted in making district-heating available is, in the opinion of the electricity supply industry, desirable from the point of view of energy policy; further it gives advantages to the whole national economy without any adverse effect on the special interests of the electric power economy.

Schlachter, H. Comments on the Situation of the Electric Power Industry. (Farbwerke Hoechst A.G., Frankfurt am Main (Germany, F.R.)). WIK (Ver. Ind. Kraftwirtsch.) Mitt.; No. 5/6, 94-96 (Jan 1976).

After some preliminary remarks on the necessity of energy supply without central control according to market economy aspects, past experience with dual-purpose power plants as an opportunity

for energy conservation in the industrial sector is pointed out. This statement is corroborated by data on the stock of monitored steam generators and boilers. The data cover a period early in 1975 and 1974 and are classified according to groups of industry or trade.

Schueller, K.H. Gas Turbine Thermal Power Station. (to Brown, Boveri and Cie A.G., Mannheim (Germany, F.R.)). German (FRG) Patent 2,512,774/A/. 30 Sep 1976. p. 13.

This patent is concerned with the special equipment and switching of a thermal power station with as high a utilization of the fuel as possible at high power generation with back pressure operation. One starts from the assumption that inside an area to be supplied with district heating there are groups of consumers for whom connection via pipelines is not economic because there is no hot water circulation system available for space heating, or such a system cannot be installed because the heat flow density is too low or the distance is too great. To supply such groups a 'heating turbine' with generator is provided apart from the gas turbine driven generator supplying the general supply network. This turbine set, fed with steam from a waste heat boiler heated with waste gas from the gas turbine, only supplies heat for these groups of consumers. The water for the heating network is heated with waste steam of the heating turbine, either in the low temperature area of the waste heat boiler or in water heaters. The calorific value of the fuel is used optimally in all load conditions by the further equipment of the plant with by-passes, temperature measuring positions, controllers and controlled valves, and by parallel controllable water heating in a steam or flue gas heated section. An auxiliary combustion chamber between gas turbine and waste heat boiler makes it possible to cover the peak demand.

Shin, J.I. and M.J. Driscoll. Conceptual Design of a Small HTGR for Total Energy Applications at Military Installations. Final report. (Massachusetts Inst of Tech., Cambridge (USA). Dept. of Nuclear Engineering). May 1975.

A conceptual design for a small HTGR in the 100 MWe size range is described. The reactor drives indirect closed-cycle gas turbine power conversion units using helium as the working fluid and provides both electricity and thermal energy (via a 380 F hot-water utility system) to serve the projected needs of large US Army installations and industrial facilities in the continental US in the post-1985 time frame. The overall system design combines many of the proven features of the Peach Bottom 1 reactor, the Fort St. Vrain HTGR core, and Oberhausen II turbomachinery. The major unique feature is the use of an indirect power cycle, with helium-to-helium intermediate heat exchangers. Cost estimates are summarized which indicate the ability of the gas turbine cycle to discharge waste heat at a useful temperature gives the HTGR/GT system a significant advantage over nuclear and fossil-fired Rankine systems,

even though it is inferior to LWR systems on an electric-only basis. The fossil-fired-gas-turbine total-energy concept is identified as its major competitor for the present application.

Simon, M. Solar Thermal Power Plants. (Maschinenfabrik Augsburg-Nuernberg (M.A.N.) A.G., Muenchen (Germany, F.R.). Abt. Neue Technologie, Sonnenenergieprojekte). pp. 339-347 of 1st German Solar Energy Forum. Vol. 2. Proceedings. Chapter 17: solar power stations. Bossel, U. (ed.). Muenchen, Germany, F.R.; DGS (1977).

In view of the world's limited reserves of conventional sources of energy, solar energy plants are gaining in importance. Besides the development of flat collectors for heating water and large central solar tower plants for the generation of electricity, with ratings of 1-100 MW, M.A.N. is also intensively engaged in the development of small solar thermal power plants with ratings of 15 to 500 kW. The overall efficiency of such plants increases considerably if the waste heat produced is used for refrigeration or for desalinization of seawater.

Sobol, I.D. and Yu. I Vinogradov. Procedure for Taking into Account Statistical Probability Factors in Selecting Output of Steam Generators of Industrial/Space Heating Heat and Power Stations for a Future Period. Therm. Eng. (USSR) (Engl. Transl.); 23: No. 6, 40-43(1976).

Selection of the main equipment for industrial/space heating heat and power stations amounts to determination of the structure of two assemblies: turbine units and steam generators. The type and number of turbine units of a station are in the functional dependence, which is being optimized; they depend on the size and composition of the heat demands. Determination of optimal unit steam generator output of a heat and power station for a future period is an indeterminate probability engineering and economic problem. Statistical processing of available data makes it possible to obtain arithmetic mean and mean probability estimates of expected unit output. Analysis of contingent strategies with the aid of the apparatus of engineering and economic investigations will make it possible with allowance for the indeterminacy of initial data to develop the most reliable and complete procedure for selecting the type of steam generator for the remote future.

Sokolov, E. Ya., B.V. Sananov and G.V. Ivanov. Optimisation of Joint Operational Modes of T and PT Types of District Heating Turbines (Moscow Power Inst.). Therm. Eng. (USSR) (Engl. Transl.); 22: No. 12, 13-17(Dec 1976).

Calculation of the characteristics, particularly turbine performance, of dual-purpose heat and power (h. and p.) plants is necessary to determine optimum operating conditions. It is shown that it does not suffice to determine the characteristics of an h. and p. station only by one set of average values of influencing factors

and that it is necessary to analyze the influence of contingent values of these factors on the characteristics of the h. and p. station, as well as of contingent errors in determination of input data. A method of sufficiently accurate calculation of power characteristics of an h. and p. station, based on the use of dimensionless, relative and specific quantities and mathematical models (load diagrams, turbine characteristics, etc), was developed. This method made it possible to write a comparatively simple universal program for a digital computer for calculation of power characteristics of an h. and p. station according to all major factors. The methods of planning experiments and of analysis of regression made it possible to obtain polynomials of second degree, by which one can with sufficient accuracy with minimal use of time and labor determine and analyze the characteristics of an h. and p. station with turbines of different types and select the optimal combination of turbines. These polynomials can be used to optimize cycle arrangements (power plants) of industrial enterprises which have industrial h. and p. stations having direct and return connections with other power plants.

Spencer, R.S. (Dow Chemical U.S.A., Golden, CO), W.S. Butler, M.K. Enns, and B.W. Wilkinson. Potential for Fuel Economics via Combined Steam-power Production. pp. 565-572 of Eleventh inter-society energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers (1976).

The potential for fuel savings as well as capital reductions and environmental benefits is explored for the combined generation of electric power and process steam by either industry-owned (by-product) or utility-owned (dual purpose) power plants. The technical features of such plants are discussed, and the potential for the implementation of such systems is outlined. By-product plants would be fired with coal and be capable of producing steam plus electric power by extraction turbines plus extra power via condensing turbines that would permit the match of steam versus electric power to be varied. Dual-purpose plants would be either coal- or nuclear-fueled and produce steam via extraction turbines. Additional condensing capacity would be expected due to the size of such plants. It is shown that the capital reductions of up to 16 billion dollars and fuel savings of 725,000 barrels per day of oil equivalent could be achieved by 1985 if reasonable implementation of the proposed schemes is achieved.

Spiewak, I., O.H. Klepper and L.C. Fuller. Technical and Economic Studies of Small Reactors for Supply of Electricity and Steam (Oak Ridge National Lab., Tenn. (USA)). Feb 1977.

Several years ago conventional opinion held that nuclear power plants must be very large to be competitive with fossil fuels. This situation has changed markedly in most countries within recent years, as oil and gas supplies have become more scarce and costly. Studies have been carried out for several nuclear steam supply

systems in the small and intermediate size range. Detail studies are reported of the Consolidated Nuclear Steam Generator (CNSG), a 365 MW(th) pressurized water reactor being developed by Babcock and Wilcox, as applied to industrial energy needs. Both conventional and barge-mounted nuclear steam supply systems are considered. Conceptual studies have been started of pressurized and boiling water reactors in the range of 1000 MW(th), which are envisioned for utility operation for supply of electric power and steam. Design studies of a 500 MW(th) high temperature reactor are also reported. The small reactors are expected to have higher unit costs than the large commercial plants, but to have compensating advantages in higher plant availability, shorter construction schedule, and greater siting flexibility. Studies are also reported of power cycle parameters and cost allocations for extraction of steam from steam turbine plants. This steam could be used for industrial energy, district heating, or desalination.

Steinber, M. Combined Coal and Nuclear Plants for Power, Heat, and Synthetic Fuels. (Brookhaven National Lab., Upton, NY). (1977).

Stetkar, J.W.; F.R. Best, M.W. Golay. Design of a Nuclear Powered Total Energy System for Fort Bragg, North Carolina. Final Report. (Massachusetts Inst. of Tech., Cambridge (USA). Dept. of Nuclear Engineering). 31 May 1976. p. 306.

A Total Energy System (TES) is designed to supply the thermal and electrical energy requirements of Fort Bragg, North Carolina for a period of 30 years, with startup scheduled for early 1985. Considered for use as the central station power plant for this system are a combined coal gasification, fossil-fired gas turbine (CGGT) power plant and a direct Brayton cycle high-temperature gas-cooled reactor, helium gas turbine (HTGR/GT) power plant. Several utility system configurations affording different thermal/ electrical energy demand ratios are studied for each supply option. With the primary system optimization criterion being the choice of the TES providing a minimum of total energy costs over the system lifetime, it is found that the optimal thermal/electrical load split for each supply option occurs at approximately 75% of the base's total energy demands supplied thermally. Within the limits of the unit-cost assumptions made and for the range of cases studied, it is found that the present-worth total cost of the optimized HTGR/GR system (in 1985 dollars) is \$245.7 million and the corresponding optimal system cost for the fossil CGGT alternative is \$181.7 million. Further studies are recommended to investigate the sensitivity of this 26% cost differential to variations in the mode of power plant operation and to design modifications in the thermal energy distribution piping network.

Tillequin, J. Improvements in Installations for the Combined Generation of Electrical Energy and Thermal Energy. (to Fives-Cail-Babcock). 17 Apr 1974. p. 7. (In French).

Description is given of an installation for the combined production of electrical energy and thermal energy, comprising a steam-generator adapted to feed a turbo-alternator simultaneously with a heat-using plant. That installation is characterized in that it comprises a heat-accumulator capable of storing, as desired, heat coming from the basic thermal source and of giving back, as desired, the heat thus stored, the circuit for giving back heat being so arranged that said heat be delivered, at least partly, to the plant heat-distribution network. This can be applied to providing a seawater de-salting plant fed by a nuclear boiler with a make-up heating.

Tokarev, Yu.I.; I.N. Sokolov, S.A. Skvortsov, A.M. Sidorov, L.V. Krauze. Boiling Water Reactor in a Prestressed Reinforced Concrete Vessel for an Atomic Central Heating-and-Power Plant. (Inst. of Atomic Energy, Moscow). (Apr 1987).

The possibility of using a boiling water reactor in a prestressed reinforced concrete vessel for an atomic central heating-and-power plant (CHPP) was considered, with design features of the reactor intended for a two-purpose plant. A prestressed reinforced concrete vessel and integral arrangement of the primary circuit ensured reliability of the atomic CHPP using various CHPP flowsheets.

Vanek, V.; O. Suchanek. Possible Uses of Nuclear Energy in Agriculture. (Mar 1977). (In Czech).

The possibilities are indicated of building nuplexes around a nuclear source producing cheap energy in the form of electricity, steam or hot water. Nuclear power plant warm process water will be used for heating hot-houses, irrigating fields and breeding thermophilic fish. The application of radionuclides and ionizing radiation in agriculture is indicated.

Vinogradnik, M.V.; A.T. Kurnosov, E.S. Klimovskikh. Method of Compiling Algorithms and Programs for Digital Computers to Optimize Load Distribution Among Turbine Units of Heat-and-Power Stations. (Dnepropetrovsk Eng-Constr Inst, Ukr SSR). (1977). (In Russian).

A method of optimal load distribution between turbine units of heat-and-power plants by means of a computer is worked out. The main principles of the method are described and an example of its application to a particular heat-and-power station scheme is presented. It is shown how to apply the computer-aided calculation programs compiled in accordance with the above method.

Weise, A. When is it Worthwhile to Generate One's Own Power. (Sep 1976). (In German).

This article attempts to prove that the coupling of power (to generate electric power or for direct drives) and heat (product heat, space heating) is economical even in small and medium-sized plants. The author omits that the coupling of these two processes does not only help to save fuels (costs and foreign currency) but also reduces the load on the environment. Considering the high cost to the state due to environmental pollution, the industry's attempts to reduce environmental loads in this way ought to be better appreciated.

Widmer, T.F. MA. Summary Assessment of Electricity Cogeneration in Industry. Thermo Electron Corporation (1977). p. 8.

Data on electric power and industrial process-heat cogeneration are summarized. A program for promoting industrial congeneration by changing regulatory policies and tax incentives is discussed. The potential capacity for cogeneration in U.S. industry is estimated for differing sets of policy assumptions. The potential savings in fuel and capital investment that could result from cogeneration are described. It is estimated that for 50,000 MW of added cogeneration capacity in 1985 as compared with 1975, 588,000 bbl/d of fuel could be saved relative to the fuel consumed by fossil-fuel power plants to produce that amount of electric power and that the net capital savings would be \$24 billion.

Zimmermann, K. Jeddah 2 Power Station. (1977). (In German).

This article gives a brief survey of the combined power station and desalination plant Jeddah 2 by the Red Sea (Saudi Arabia). The plant is under construction. It is planned to take the first block in operation at the end of 1977. The power plant is to supply 2 x 42 MW electric power and 40,000 m³ drinking water daily.

Zykov, S.A.; D.M. Budnyatskii, V.M. Kuz'min, M.N. Zaovrazhnova, V.P. Radosh. Justification of the Parameters and Characteristics of Saturated Steam Turbines for High-Capacity District Heating Power Plants. (Apr 1975). (In Russian).

Selection of the profile, for initial and final parameters of turbines for large district heating power plants (nuclear power plants) with light water reactors is substantiated. A rough technical and economic comparison is made between nuclear heat-and-power plants and other sources of power supply using nuclear and organic fuels. It is concluded that nuclear heat-and-power plants with one 1000 MW pressurized water reactor and two TK-450-500-60 turbines are the most efficient for areas in the European part of the USSR with thermal loads between 1000 and 2000 Gcal/hr.

APPENDIX J
POWER PLANT BIBLIOGRAPHY

POWER PLANTS

Power Plant Economic Model Program Description and User's Guide. (Aerospace Corp., El Segundo, Calif. (USA). Energy and Resources Div.). 1 Jun 1974. p. 107.

The Aerospace Corporation Power Economic Model was developed to provide an analytic tool for comparing the economics of alternative types of power plants. In addition, by comparing the capital investment requirements and operating costs of alternative solar systems, preferred concepts can be identified. The economic feasibility of these preferred systems can be determined by comparative economic evaluation of these and conventional nuclear and fossil-power plants for identical periods of commercial operations.

Duel-Energy-Use-System Workshop Summary. (Electric Power Research Inst., Palo Alto, Calif. (USA)). Mar 1978. p. 93.

Results of EPRI's Duel-Energy-Use-Systems (DEUS) Workshop held September 19-23, 1977, in Yarmouth, Maine, are presented. Participants from the electric utility industry, industrial and other consumer experts, government representatives, academicians, and equipment manufacturers met to discuss and evaluate the various options for using thermal and electric energy produced from a common source. Work sessions based on formal presentations and group discussion resulted in a list of 32 R, D, and D projects of potential interest to state and Federal program managers as well as to utility personnel. A resource document, which should be useful to utilities in the process of developing programs related to DEUS, was compiled from the workshop presentations. The application areas reviewed were: district heating, co-generation, use of power plant reject heat, total energy applications, and emerging technologies with potential for simultaneous production of heat and power. Each type of application was covered in some detail. This report presents an overview of the workshop sessions, lists the research projects identified, and contains abstracts of the 35 papers presented.

Utility Analysis of Coal Transportation Availability. Final Report. (Energy Resources Co., Inc., Cambridge, Mass. (USA)). 15 Sep 1976. p. 160.

Under the Energy Supply and Environmental Coordination Act of 1974, the Federal Energy Administration was directed to serve to certain electric utility and industrial power plants prohibition orders restricting them from burning petroleum products and/or natural gas as their primary energy sources and, thus, necessitating conversion

to coal. This study seeks to determine if the transportation systems and facilities servicing first-round ESECA-candidate electric utility power plants are adequate to support a finding of transportation availability for those plants. The study identifies, characterizes, and documents transportation systems availability for each ESECA plant with respect to the following areas: (1) trunk lines from coal-supply region to demand region, including mode, ownership, and capacity; (2) spur lines from trunk lines to plants, including mode, ownership, capacity, and structural integrity; (3) mine-site loading and plant-unloading facilities, including ownership, capacity, and needed construction or refurbishment; and (4) economically feasible alternative systems for purposes of fallback routes if the primary route should become inadequate. The modes of transport considered included railroad rolling stock (general, unit, and integral trains), barges, and trucks. A time frame of 1976 to 1985 (inclusive) was used.

California Energy Trends and Choices. Volume VII. Power Plant Siting. Sacramento, CA; Energy Resources Conservation and Development Commission (1977). p. 73.

The report is prepared as required by the California Public Resources Code and State Energy Commission orders. The following are included in Chapter I of this report: a list, including maps, of existing electric generating sites; a list, including maps, of sites and potential multiple facility sites which have been found to be acceptable to the Public Resources Code; a selected list of those factors that might be considered in determining whether an area is either suitable or unsuitable for power plant siting and a discussion of how those factors might be used; and a list, including maps, of possible areas that are appropriate for additional electrical generating sites. Chapter II deals with the constraints upon the selection of sites for power plants.

Preliminary Survey of Some Major Factors Bearing on the Feasibility of Energy Centers in Michigan. Executive Summary. Draft for Review. (Environmental Research Inst. of Michigan, Ann Arbor (USA)). Mar 1977, p. 48.

A preliminary survey of the principal technical, economic, environmental, legal/regulatory, and social factors bearing on the feasibility of locating, constructing, and operating energy centers in the State of Michigan was conducted. This executive summary describes (1) the physical characteristics of two study sites in Michigan on or near the Great Lakes, (2) the technical characteristics and configuration of an energy center which could be located at these sites, including the centralized power-generating facility and the colocated industrial and agricultural energy users, and (3) the characteristics of the harbor and urban development associated with the energy center. The summary then goes on to discuss the principal factors and impacts, as well as to identify problem areas and key issues. It also presents recommendations for further study suggested by this survey.

. Study of Benefits of Improved Power Plant Reliability and Productivity. Phase 1 Report. Factors Considered in Planning Generation. (General Electric Co., Washington, D.C. (USA)). Feb 1978. p. 250.

In March, 1975, a Federal Interagency Task Group published a report entitled, "A Report on Improving the Productivity of Electric Power Plants". One of the recommendations of the report was that an appropriate agency should analyze and report on the benefits of improved power plant reliability. This two-phase contract is an outgrowth of that recommendation. The first phase describes the current state-of-the-art utility generation planning, noting what factors are currently considered and the role played by power plant productivity, what methodologies are used by planners, and how the planning results from these methodologies are implemented. In this context, a preliminary determination is made of how increased goals of reducing consumption of oil and natural gas, mitigating rising electricity costs to the consumer, and reducing the amount of new electric-generating capacity required and the capital investment associated with it. Ten utilities provided input to this first-phase report. The second phase of the contract, to be reported on in the fourth quarter of 1977, was to conduct an in-depth study of the benefits of improved nuclear and coal power plant productivity, based upon an analysis of two utility systems that have wide differences in generation fuel mix.

. Study of Benefits of Improved Power Plant Reliability and Productivity. Phase 2 Report. Analysis of Two Utility Systems and Regions. (General Electric Co., Washington, D.C. (USA). Center for Energy Systems). 30 Dec 1977. p. 228.

In March 1975, a Federal Interagency Task Group published a report entitled, "A Report on Improving the Productivity of Electric Power Plants". One of the recommendations of the report was that an appropriate Federal agency analyze and report on the benefits of improved power-plant reliability. This two-phase contract is an outgrowth of that recommendation. The objective of the first phase was to describe the current state-of-the-art of utility generation planning, noting what factors are currently considered and the role played by power-plant productivity, what methodologies are used by planners, and how the planning results from these methodologies are implemented. The objective of the second phase of the contract is a study of the potential benefits of improved nuclear and coal power plant productivity, based upon an analysis of two utility systems that have wide differences in generation fuel mix. The simulated benefits are quantified using models of each of the utility systems, as well as models for two large multi-state regions within which the utility systems operate. Participants in this second phase of the study are the Detroit Edison Company, the New England Power Pool, and the Northeast Utilities Company which is a member of the New England Power Pool.

. Study of Benefits of Improved Power Plant Reliability and Productivity. Phase 3 Report. National Analysis. (General Electric Co., Washington, D.C. (USA). Center for Energy Systems). 30 Dec 1977. p. 74.

In March 1975, a Federal Interagency Task Group published a report entitled "A Report on Improving the Productivity of Electric Power Plants." Further analysis of the benefits of improved power plant reliability was recommended, resulting in this three-phase contract. The objective of the first phase was to describe the role played by power plant productivity in electric utility planning. The second phase was an in-depth study of the benefits of improving coal and nuclear power plants on two specific utility power systems, New England Power Pool, and Detroit Edison. The third phase of this contract is the extension of the second phase to an assessment of the potential benefits to the entire nation. The same methodology employed in the in-depth analysis of Phase II is applied, but on a regional basis. This study sought to assess potential national benefits of improving by 5% both the forced outage and planned outage rates of base-load coal and nuclear units. This 5% improvement was postulated to begin in 1978 and would be achieved by 1985. Currently, the forced and planned outage rates of base-load coal and nuclear units are in the range of 15%. Thus, the 5% improvement would decrease these outage rates to approximately 10%. In performing these studies, neither the costs of implementing the productivity improvements nor the feasibility of attaining the improvements were included. The results reported in this study are the potential benefits and do not include any capital costs and O and M costs which may be required to improve power plant productivity. Chapter 2 presents the study parameters, methodology, and procedure, Chapter 3 regional results including potential oil and natural gas savings and potential economic savings, and Chapter 4 aggregate national results.

. Technical and Economic Evaluation of Recycled Industrial Secondary Products for the Preparation of Synthetic Highway Building Aggregates. (IU Conversion Systems, Inc., Philadelphia, Pa. (USA)). Jul 1974. p. 73.

The results and tabulated data are given of a study of the supply and proposed use of lime fly ash sulfate sludge compositions as a substitute for conventional road building materials. It was found that this use would be economically feasible and environmentally beneficial. Pollution problems would be solved, and, at the same time, highway construction material would be provided within the state of West Virginia.

. National Pollutant Discharge Elimination System
Adjudicatory Hearing Proceedings: Decisions of the Adminis-
trator and Decisions of the General Counsel. Volume I. Sep-
tember 1974--December 1975. (Lockheed Electronics Co., Webster,
Tex. (USA)). 1976. p. 425.

This collection contains all decisions of the Environmental Protection Agency Administrator under the Federal Water Pollution Control Act and the corresponding NPDES regulations, including denials of petitions for review, and decisions of the General Counsel reached under these procedures through the end of 1975. Subsequent decisions will be compiled in future volumes. Industries appealing actions include petroleum, metals, coal, minerals, electric utilities and municipalities. Waste disposal litigation encompasses both liquid and solid effluents from municipal, agricultural and industrial wastes.

. Powerplant Productivity Improvement Study. Volumes
I-IV. (Mechanics Research, Inc., Los Angeles, Calif. (USA)). Feb
1978. p. 693.

The Powerplant Productivity Improvement Study is presented in 4 volumes in this document. Volume I gives information on methods and techniques for determining the underlying causes and corrective actions of lost power plant productivity. Volume II includes a technical summary, step-by-step procedures, and reviews of case histories (Marshall Steam Plant Unit 4 and Turkey Point Unit 4) to discuss productivity improvement. Volume II investigates cost and performance analysis methods. Volume IV is concerned with the cost/benefit analysis of selected power plant improvement programs (Marshall and Turkey Point improvement programs). Much additional data are included in appendices to each volume.

. Power Plant Productivity Improvement Study. Appendices
1--4. (Mechanics Research, Inc., Los Angeles, Calif. (USA)). Feb
1978. p. 486.

These appendices summarize the investigation of the underlying causes of lost power plant productivity at 4 installations-- Widows Creek Unit 8, Marshall Unit 4, Turkey Point Unit 4, and Oconee Unit 1. Corrective actions that would help reduce this productivity loss are determined. The methods and techniques developed for determining the causes and corrective actions are documented in the main body of the Phase A report.

Powerplant Productivity Improvement Study. Summary Report. (Mechanics Research, Inc., Los Angeles, Calif. (USA)). Feb 1978. p. 60.

In 1974, the Federal Energy Administration initiated a program to improve the productivity of electric power plants as part of its efforts to reduce dependence on imported oil and natural gas; this resulted in many reports and recommendations being made available to industry and government organizations. The work documented in this report is aimed at formalizing the problem-analysis techniques used in the previous studies and provides techniques for assessing and monitoring the cost and benefits of problem resolution. The scope of work is as follows: documents in-depth techniques for tracing poor productivity to its root causes, develops analytic methods for estimating improvements in unit performance resulting from improved component and subsystem reliability, documents methods for estimating cost effectiveness of specific power plant productivity improvement projects, and defines methods for tracking costs and productivity improvements. The report includes examples of the use of these techniques and methods to verify their usefulness in real power plants (Duke, TVA, and Florida Power and Light).

Systems Descriptions and Engineering Costs For Solar-Related Technologies. Volume I. Summary. (Mitre Corp., McLean, VA (USA). METREK Div.). Jun 1977. p. 157.

The results of the METREK solar energy engineering cost study, in support of the System to Project Utilization of Renewable Resources (SPURR) model, are presented. Generic systems designs are formulated and the associated engineering costs are evaluated and estimated. An aim of this study is to predict the likely costs and performance of solar equipment, once mass produced. The data have been summarized on generic design data forms and are presented. The systems are grouped into four major categories by application type: (1) electric utility applications, (2) solar heating and cooling of buildings (SHAdesignment contractorsOB), (3) agricultural and industrial process heat (A.IPH), and (4) synthetic fuels and products (SFP). The electric utility application data are presented for five classes of systems: baseload, intermediate, semi-peaking, peaking and "fuel savers". Fuel savers are solar electric options without storage or backup. The SHACOB data are presented for five system types covering a wide range in demand load. These systems include domestic hot water only (liquid); heating and hot water (air and liquid); heating cooling by absorption air-conditioning, and hot water (liquid); and heating cooling and hot water with heat pump auxiliary (liquid). The A/IPH data are presented for eight applications using water, air and steam at delivery temperatures ranging from 40 to 800°C. System performance is estimated for nine locations representative of the census regions in climate, with proximity to industrial centers of concentration. The SFP data are delineated by product type.

The only product applications considered are low and medium Btu gas, synthetic (high Btu) natural gas (SNG), synthetic crude oil (syncrude), methanol and ammonia. Costs for SFP systems are developed for biomass feedstocks, high sulfur coal, oil shale, and an equatorially-located ocean thermal energy conversion (OTEC) system.

. Survey of New York Surface Water Temperatures.
Aerial Infrared Surveys of Thermal Discharges From Electric Generating Stations into New York State Waters. Final Report. (New York State Atomic and Space Development Authority, N.Y. (USA)). Sep 1974. p. 65.

Quantitative measurements of cooling water discharges from electric generating plants into waterways are needed in order to evaluate the environmental impacts of these discharges. Aerial infrared sensing enables synoptic mapping of the temperature distribution over a large expanse of water surface. Application of the infrared method is illustrated by a series of flights made over the Hudson River. Thermal discharge plumes were measured at four power stations--Albany, Danskammer Point, Indian Point and Lovett. Effects observed include tidal currents, local counter-currents, recirculation of discharged water, thermal striation, and mixing.

. Ozarks Region Energy Alternatives Study. Working Paper II. Power Generation Energy Requirements. Princeton, NJ; Mathtech, Inc. (1977). p. 100.

This Working Paper examines the potential fuel use for power generation in the Ozarks Region by state. Power-generation capacities by fuel type are estimated, and the potential capital costs required and probable environmental impacts are calculated. Gas requirements for power generation are estimated based on the planned mix of power generation facilities, and "minimum gas use" policies are examined to estimate possible gas savings.

. Case Study Applications of Venture Analysis. Eighth Monthly Report, April and May 1978. (Thermo Electron Corp., Waltham, MA (USA)). Jun 1978. p. 32.

This is the eighth monthly progress report for "Case Study Applications of Venture Analysis." The case studies to be performed are for: (1) a steam Rankine system producing electric power from waste heat (performed first), and (2) a coal derived fuel-fired diesel. The Draft Report for Case Study No. 1 has been completed. Work is continuing on the second case study. The capital costs for coal and coal-derived fuel-fired diesels are given for systems from a few megawatts to 1000 megawatts. Synthetic fuels and the economics of their manufacture are discussed. Competing technologies for central station utility applications are outlined.

Implementation Plan Review for Nevada Required by the Energy Supply and Environmental Coordination Act. Final Report. (TRW/Environmental Services, Redondo Beach, Calif. (USA)). Feb 1975. p. 49.

An Environmental Protection Agency report is given to the state indicating where control regulations for stationary fuel combustion sources can be revised without interfering with attainment and maintenance of the national ambient air quality standards. The changes would make it possible to alter fuel resource allocations to provide clean fuel savings in a manner consistent with environmental and national energy needs.

Implementation Plan Review for Iowa as Required by the Energy Supply and Environmental Coordination Act. Final Report. (TRW/Environmental Services, Redondo Beach, Calif. (USA)). Feb 1975. p. 70.

Section IV of the Energy Supply and Environmental Coordination Act of 1974 (ESECA) requires EPA to review each State Implementation Plan (SIP) to determine if revisions can be made to control regulations for stationary fuel combustion sources without interfering with the attainment and maintenance of the national ambient air quality standards. This document, which is also required by Section IV of ESECA, is EPA's report to the State indicating where regulations might be revised.

Inventory of Power Plants in the United States. (Department of Energy, Washington, D.C. (USA). Office of Utility Project Operations). Dec 1977. p. 386.

The purpose of this inventory of powerplants is to provide a ready reference for planners whose focus is on the state, standard Federal region, and/or national level. Thus the inventory is compiled alphabetically by state within standard Federal regions. The units are listed alphabetically within electric utility systems which in turn are listed alphabetically within states. The locations are identified to county level according to the Federal Information Processing Standards Publication Counties and County Equivalents of the States of the United States. Data compiled include existing and projected electrical generation units, jointly owned units, and projected construction units.

Plant and Ownership List. Supplementary to the Maps Entitled Principal Electric Facilities, 1978, Based on Data to June 30, 1977. (Department of Energy, Washington, DC (USA). Energy Information Administration). Jun 1978. p. 94.

Tabulated data are presented for locating U.S. power plants on previously published maps entitled "Principal Electric Facilities 1978." In addition to map number and location coordinates, the power plants in each state are identified by name regional electrical reliability council area, MW capacity, type of power unit, and name of owner.

. An Analysis of the Impact on the Electric Utility Industry of Alternative Approaches to Significant Deterioration. Volume II. Technical Support Document. (Federal Energy Administration. Washington, D.C. (USA)). Oct 1975. p. 148.

An evaluation is given of the impacts that various approaches to preventing significant deterioration of air quality might have on the electric utility industry. It estimates the impact that EPA regulations and recent proposals by the Senate and House subcommittees could have on the size and siting of powerplants. The primary divisions of this volume are study objectives and approach, limitations imposed on powerplants by alternative class II and III increments, impact of designation of class I areas, cumulative impact of class I, II, and III limitations, limitations of the study, and recommendations for further study. Appendices include U.S. environmental protection agency regulations for prevention of significant air quality deterioration, fundamental theory of impact prediction and the buffer zone concept, methodology for class II impact analysis, power plant sample data base, selected definitions.

. An Analysis of the Impact on the Electric Utility Industry of Alternative Approaches to Significant Deterioration. Volume I. Executive Summary. (Federal Energy Administration, Washington, D.C. (USA)). Oct 1975. p. 53.

An evaluation is given of the impact of proposed Senate, House, and EPA regulations regarding significant deterioration of air quality on the electric utility industry. The following issues are evaluated: aggregate impact of significant deterioration requirements on new coal-fired power plants; implications of Class I area designations; impact of alternative Class II increments; implications of stack height limitations; and minimum degree of emission control.

. Inventory of Power Plants in the United States. (Federal Energy Administration. Washington, D.C. (USA)). Jun 1977. p. 357.

The purpose of this inventory of power plants is to provide a ready reference for planners whose focus is on state, standard Federal region, and/or national level. Thus the inventory is compiled alphabetically by state within standard Federal regions. The units are listed alphabetically within electric utility systems which in turn are listed alphabetically within states. The locations are identified to county level according to the Federal Information Processing standards Publications. FIPS PUB 6-2, Counties and County Equivalents of the States of the United States, published by the US Department of Commerce.

. Survey of Electric Utility Power Plant Delays.
Summary Report. (Federal Energy Administration, Washington, D.C.
(USA). Office of Energy Resource Development). 1 Sep 1975. p. 41.

This report presents the findings of a Federal Energy Administration survey of utilities reporting delays in construction of generating facilities. A 30-day survey of power plant problems was inaugurated by FEA with the objectives of verifying, updating, and expanding the available data on powerplant delays; indentifying current action; and identifying where a Task Force effort could be used most effectively. The following problems facing electric utilities are analyzed: financing, demand, nuclear licensing, siting and regulation and environmental licensing, labor, equipment, Federal Power Commission requirements. An additional section includes reports on meetings with consumer and environmental groups, financial groups, and construction industry and equipment manufacturers.

. Electrical Generating Plant Availability. (Federal
Power Commission, Washington, D.C. (USA). Bureau of Power). May
1975. p. 63.

A discussion is given of actions that can improve availability, including the following: the meaning of power plant availability; The organization of the electric power industry; some general considerations of availability; the improvement of power plant availability--design factors, control of shipping and construction, maintenance, operating practices; sources of statistics on generating plant availability; effects of reducing forced outage rates; and comments by electric utilities on generating unit availability.

. The Phasing Out of Natural Gas and Oil for Electric
Power Generation. Southwest Power Pool and Electric Reliability
Council of Texas. Par I. Present Electric Utility Program. 1975-
1984. (Federal Power Commission, Fort Worth, Tex. (USA). Bureau of
Power). Sep 1975. p. 46.

A report is given of electric utility plans for phasing out natural gas and oil for electric generation in the Southwest Power Pool and Electric Reliability Council of Texas. These two electric reliability councils cover all or parts of eight states ranging from the western part of Mississippi to the eastern part of New Mexico and stretching from Texas to Kansas and part of Missouri. Because this area is heavily dependent on natural gas as a fuel for electric generation, the use of natural gas is of major concern and importance in the face of a diminishing supply.

. Regional Factors in Planning and Siting Electrical
Energy Facilities in the Western States. (Western Interstate
Nuclear Board, Lakewood, Colo. (USA)). 5 Apr 1977.

A summary of a study directed at identifying the problem in planning and siting nuclear and other electrical energy facilities in the Western Interstate Nuclear Board region is presented.

Adkins, A. Low-Risk Construction Contracts: A Way Out. (Allen Associates, Westport, CT). (15 Sep 1976).

A new solution for reducing power-plant construction costs is being offered by Morrison-Knudsen, Inc., Boise, Idaho. The low-risk contract contains the key ingredient that owners and contractors want: the incentive for getting the job done at the lowest possible cost at a reasonable profit. The underlying concept behind the low-risk contract is that it creates an agreement which permits the owner and contractor to participate in a joint, semifixed cost/profit-sharing team effort. Both share the risks, the cost savings, the cost overruns, and the implications of design changes, delays, etc. The other key element of low-risk contracting is the sliding-fee incentive, which distinguishes it from the usual cost-reimbursable contract. While the details of each low-risk construction contract will vary, each contains an agreed-upon: (1) initial target-cost estimate; (2) adjusted target-cost estimate; (3) sliding-fee formula; and (4) final cost determination. The initial target-cost estimate is the total of the costs of specific lump-sum items, plus the cost of specific reimbursable items.

Alefeid, G. Methods for Conveying and Utilization of Waste Heat From Power Plants. (Tech Univ., Munich, Ger.). (Mar 1977). (In German).

The article considers the use of high-pressure gas, such as ammonia or propane, as a media for cooling of power plant condensers, which is then fed into pipelines to consumers for heat recovery. The same gas would be returned as a liquid to the power plant. This system makes it possible to lower the condenser temperature to 30 to 25°C, resulting in an improved efficiency of the power station of 36 to 39%, compared to the cooling tower operation at 33%.

Allemann, R.T.; B.M. Johnson, D.W. Faletti, G.C. Smith, R.D. Tokarz, R.A. Walter. Evaluation of Alternative Dry/Wet Cooling Concepts For Power Stations. (Battelle Pacific Northwest Lab., Richland, WA). (Jun 1977).

Babailov, E.P.; Yu.P. Shchev'ev. Sound Insulating Efficacy of a Two-Layered Elastic Housing for Power Installations. (Leningrad Metal Works, USSR). (1977). (In Russian).

The mechanics of passage of the sound energy through a two-layered elastic housing is considered and the sound insulating efficacy of such a housing is established on the example of two semispherical concentric elastic shells simply supported by an absolutely rigid foundation. Calculations show a sharp increase in the efficacy of sound insulation, in the case of a two-layered housing, within the entire range of frequencies including discrete resonance frequencies characteristic for a single-layered housing.

Barnthouse, L.W.; J.B. Cannon, S.G. Christensen. Selective Analysis of Power Plant Operation on the Hudson River with Emphasis on the Bowline Point Generating Station. Volume 1. Jul 1977.

A comprehensive study of the effects of power plant operation on the Hudson River was conducted. The study included thermal, biological, and air quality effects of existing and planned electrical generating stations. This section on thermal impacts presents a comprehensive mathematical modeling and computer simulation study of the effects of heat rejection from the plants. The overall study consisted of three major parts: near-field analysis; far-field analysis; and zone-matched near-field/far-field analysis. Near-field analyses were completed for Roseton, Danskammer, and Bowline Point Generating Stations, and near-field dilution ratios range from a low of about 2 for Bowline Point and 3 for Roseton to a maximum of 6 for both plants. The far-field analysis included a critical review of existing studies and a parametric review of operating plants. The maximum thermal load case, based on hypothetical 1974 river conditions, gives the daily maximum cross-section-averaged and 2-mile-segment-averaged water temperatures as 83.80°F in the vicinity of the Indian Point Station and 83.25°F in the vicinity of the Bowline Station. This maximum case will be significantly modified if cooling towers are used at certain units. A full analysis and discussion of these cases is presented. A study of the Hudson River striped bass population is divided into the following eight subsections: distribution of striped bass eggs, larvae, and juveniles in the Hudson River; entrainment mortality factor; intake factor; impingement; effects of discharges; compensation; model estimates of percent reduction; and Hudson River striped bass stock.

Benson, D.C.; F.J. Doyle. Projects to Expand Fuel Sources in Eastern States: An Update of Information Circular 8725. Survey of Planned or Proposed Coal Mines, Coal and Noncoal Conversion Plants, Electric Generating Plants, Oil Refineries, Uranium Enrichment Facilities, and Related Infrastructure, in States East of the Mississippi River (as of July 1977). (Bureau of Mines, Washington, D.C. (USA)). 1978. p. 156.

This update of BM-IC--8725 (EAPA 3:1513) comprises tables listing the name, location, and other pertinent data concerning certain fuel-related projects. The tables include information on projects involving the proposed or planned development of fuel resources, as well as the development of storage, transportation, and conversion facilities. The report covers the 26 States east of the Mississippi River. Of the total 535 projects for which information is provided, 429 concern coal mines and electric generating plants (Including Energy Supply and Environmental Coordination Act (ESECA) coal conversion notices).

Berrie, T.W. Economic Analysis of Electric Power Projects. (World Bank, Washington, DC). (Jun 1977).

This article deals with the problem of judging whether or not a proposed electric power project is likely to benefit the economy to justify the required expenditure of public resources. The perspective is therefore economic and financial, rather than technical. Analysis relies on three types of tests, all of which employ the discounting and new techniques, the only way to give proper recognition to the time value of money: (a) the internal economic return (IER) i.e., the discount rate which equalized the present values of the benefit and cost streams over the life of the project; (b) the benefit/cost ratio (B/C ratio), a comparison of the present worth of benefits and costs based on an assumed test rate of discount; and (c) the net present worth (NPW) or the difference in present worth of benefits and costs. The significance of the opportunity cost of capital, the effects of risks and uncertainties; and assessment of benefits are discussed.

Brouns, R.J. Environmental Impacts of Nonfusion Power Systems. (Battelle Pacific Northwest Labs., Richland, Wash. (USA)). Sep 1976. p. 130.

Data were collected on the environmental effects of power sources that may be competitive with future fusion reactor power plants. Data are included on nuclear power plants using HTGR, LMBR, GCFR, LMFBFR, and molten salt reactors, fossil-fuel electric power plants; geothermal power plants; solar energy power plants, including satellite-based solar systems; wind energy power plants; ocean thermal gradient power plants, tidal energy power plants; and power plants using hydrogen and other synthetic fuels as energy sources.

Buchwald, K. Landscape Planning as a Contribution to the Assessment and Finding of Sites for Energy Facilities From an Ecological and Creative Point of View. (Technische Univ. Hannover (Germany, F.R.). Inst, fuer Landschaftspflege und Naturschutz). pp vp. of Energie und Umwelt. Essen, Germany, F.R.; Vulkan-Verl. (Jun 1977). (In German).

The environmental agreeability examination through landscape planning in connection with the finding of sites for power stations and their integration into area planning is explained. The procedure of landscape planning for the assessment of power station sites is also presented.

Chait, I.L. Energy Conservation With Advanced Power Generating Systems. (Burns and Roe, Inc., Hempstead, NY). pp 547-553 of In Eleventh Intersociety Energy Conversion Engineering Conference. Vol. 1. New York; American Institute of Chemical Engineers (1976).

Plant thermal efficiencies of central power stations have evolved from the low 20's to the high 30's since the 1920's. During the last 20 years, a downward trend has developed due to a combination of environmental regulations, more severe operating conditions, and the need to move away from the use of petroleum fuels to nuclear, coal, and lower grade fuels. Fossil-fired power generating plants based on advanced power conversion systems--such as magnetohydrodynamics, fuel cells, and advanced steam and gas turbines in various configurations--have the potential for regaining some of the lost thermal efficiency. The combined power demand of the auxiliaries associated with the advanced cycle and processes may exceed the totals in terms of percent output of present day plants. Unless these auxiliary loads are minimized, they may so reduce the overall plant thermal efficiency that the hoped for resumption of a steady improvement in plant heat rates may not materialize. Significant gains in energy conservation can be anticipated from efforts to optimize the balance-of-plant power requirements from improvements and application of more efficient auxiliary equipment and systems in plants using advanced power generating cycles.

Christensen, S.W.; D.L. DeAngelis, A.G. Clark. Development of a Stock-Progeny Model for Assessing Power Plant Effects on Fish Populations. (Oak Ridge National Lab., Tenn. (USA)). 1977. p. 30.

A multi-age-class model based on simple but general biological principles, was developed to assess the impact of power plants on fish populations. The model is then parameterized in order to produce a variety of stock-progeny relationships, assuming that the stock is always at stable age distribution. The predicted response of the fish stock to power plant cropping of young-of-the-year fish is investigated for each of these stock-progeny relationships. In general, the sensitivity of the equilibrium stock size to cropping is positively related to the slope of the stock-progeny curve at the equilibrium point and, to a lesser extent, negatively related to the slope of the curve at the origin. In addition, the timing of power-plant-induced mortality in relation to the timing of compensation is important. The maximum amount of power-plant-induced mortality that can be tolerated by the stock can be calculated from the slope of the curve at the origin. Application of the model to specific cases will likely need to utilize time-series simulations in addition to the steady-state approach investigated here.

Church, R.L.; J.L. Cohon. Multiobjective Location Analysis of Regional Energy Facility Siting Problems. (Brookhaven National Lab., Upton, N.Y. (USA)). Oct 1976. p. 94.

This report is one of a continuing series of policy analysis and model development studies in the area of energy facility siting prepared by the Brookhaven National Laboratory Regional Energy Studies Program. At Oak Ridge National Laboratory a sophisticated approach based on political interaction analysis has been developed as an adjunct to their siting model, allowing resolution of regional siting issues in the context of a prediction of political feasibility (Yaffee, 1976). At Brookhaven, emphasis has been on the development of operations research approaches that could interface with the ensemble of energy systems analysis models resident at BNL's National Center for Analysis of Energy Systems, and the regional environmental impact models at the BNL Atmospheric and Oceanographic Sciences divisions (Meier, 1975). As an initial step in the development of such an operations research approach to regional siting policy analysis, this report presents an exploratory analysis of two areas of inquiry that appear especially promising. The first, examined in Chapter II, rests on the application of location theory, an area of inquiry that has seen a strong resurgence in the recent mathematical geography and regional economics literature as a result of its ability to address a rather large number of facility planning problems, in both the private and public sectors. The second area of inquiry, the focus of Chapter III, is multi-objective programming, a formalization of the notion that siting decision making is an adversary process, in which a resolution of conflicting objectives is the key issue. Multi-objective location modeling, a merger of the two areas of inquiry, may provide a useful analytical framework for regional energy planning. The Regional Energy Facility Location Model, which is based on such a merger, is presented in Chapter IV, and various extensions of the basic model formulation are presented in Appendices.

Clark, W.F. (ed.). Fort Union Coal Field Symposium, Billings, Montana, April 25--26, 1975. Volume 2. Aquatic Ecosystems Section. Billings, MT; Eastern Montana College (1975). p. 136.

Vol. 2 of the proceedings of the symposium, sponsored by the Montana Academy of Sciences and held at Eastern Montana College, Billings, includes 12 papers, each indexed separately for the ERDA Energy Data Base. The papers involve studies of specific river aquatic ecosystems and their changes along the rivers, seasonal variations, species diversity, etc. as a base for measuring the effects of coal mining, power plants, and coal-gasification plants resulting from water withdrawal, waste water, and waste heat effluents. Some papers deal with hydrology and water resources availability and planning in the area.

Cleveland, E.B.; R.J. Duphily, G.L. Stiehl, C.B. Morrison. Power Plant Data Systems. Final Report. (Delta Electronic Control Corp., Irvine, Calif. (USA)). Mar 1978. p. 169.

As the cost of electric power rises and reserve margins dwindle, pressure on the industry builds to make generating units more productive; i.e., the ability of a generating unit to produce electric power efficiently and reliably. Historical data are needed now to determine just how productive generating units are. These data will aid in the improvement of deficient units and the design of new ones. Several data systems now exist that collect and report certain kinds of data from operating units. This study was undertaken to determine what kind of data are needed and how the information can best be provided. All known existing data systems were examined. Several data systems serving other industries were studied to search for methods useful to the collection and dissemination of generating-unit data. The results of these Phase 1 study efforts were published in EPRI-NP-543. The conclusion of the Phase 1 investigations made it apparent to the study team that none of the existing data systems completely satisfies the needs of industry and government agencies. During Phase 2 these unfulfilled needs were identified and a Data Collection and Dissemination Plan that would satisfy the needs for timely and complete productivity data was outlined.

Comtois, W.H. Power Plant Construction Schedules, Escalation, and Interest During Construction. (Westinghouse Electric Corp., Pittsburgh). (1976).

The purpose of this paper is to explore the schedule/cost interrelation, and to determine means by which any adverse effects can be mitigated. There are two sets of conditions under which generation projects are undertaken. The customary one is that where generation needs are projected for several years and expansion planned on the basis of load characteristics, operating policy, and economics. The other circumstance is one in which unexpected growth of load causes the implementation of a generation project on an "as soon as possible" schedule. As an aid in determining the quantitative cost effect of changes in schedule length, data are prepared which give escalation and IDC multipliers on base costs as a function of schedule. The ratio of costs under schedules which differ by stated amounts and which have the same commercial operation date is shown. Examples of problems which can be solved using the methods derived are listed and show which equations are appropriate for each case and also gives numeric results for the assumed parameters. Equations derived are based on the simplifying assumption that all payments were equally divided over the life of the project.

Coutant, C.C. Cooling Systems. Mar 1978.

Progress on the thermal effects project is reported with regard to physiology and distribution of Corbicula; power plant effects studies on burrowing mayfly populations; comparative thermal responses of largemouth bass from northern and southern populations; temperature selection by striped bass in Cherokee Reservoir; fish population studies; and predictive thermoregulation by fishes. Progress is also reported on the following: cause and ecological ramifications of threadfin shade impingement; entrainment project; aquaculture project; pathogenic amoeba project; and cooling tower drift project.

Cumberland, J.H.; W. Donnelly, C.S. Gibson, Jr.. C.E. Olson. Forecasting Alternative Regional Electric Energy Requirements and Environmental Impacts for Maryland, 1970--1990. (Univ. of Maryland, College Park). pp 32-57 of In Energy, regional science and public policy. Chatterji, M.; Van Rompuy, P. (eds.). New York; Springer-Verlag (1976).

A regional rather than national solution is needed for some of the difficult energy issues, such as power plant siting, which can cause localized economic, social, and environmental hardship. Forecasts are made of Maryland electricity demand, the environmental impacts of meeting this demand, and the implications for decisions on specific power plant sites. There are seen to be many options open to local governments to control electricity demand growth by encouraging rate structures that favor energy conservation; taxing air, water, and land pollutants; and encouraging less energy-intensive activities. Local vetoes of state projects can be a useful way to develop less-damaging projects while lessening conflict between state and local governments. Good planning for peak-load pricing and service expansion can avoid supply interruptions and still promote the kinds of economic development that are socially beneficial without causing excessive damage to the environment.

Denelli, G. Evaluation of Thermal Impact of Cooling Water Discharges Into Mediterranean Coastal Waters. (ENEL, Milan). pp 763-780 of In Future energy production systems. Heat and mass transfer processes. Vol. II. Denton, J.C.; Afgan, N.H. (eds.). Washington, DC; Hemisphere Publishing Corp. (1976).

Cooling water discharges from power stations may affect the aquatic life of the receiving water body by altering its temperature level as well as its natural turbulence and velocity field. Furthermore, without a careful design of intake and outlet structures, recirculation of cooling waters at the intake may arise thus reducing the overall plant efficiency. Dispersion mechanisms of heated effluents are different as the receiving water body may be a site along the coast or an estuarine area. In coastline discharges the effluent velocity is usually high enough to give rise to a jet type turbulent entrainment of ambient waters up to a distance of several

hundred meters from the outlet, i.e., so far as the residual thermal alteration is higher or equal to 30% of the initial discharge temperature rise above ambient. Further away the temperature reduction is due mainly to turbulent diffusion induced by ambient turbulence. Estuarine areas represent a rather complex case of a receiving water body for the presence of the combined effects of several environmental factors such as: river flow, tides, sea currents, volume and time of residence of brackish waters in the lagoons. The different aspects of heated effluents dispersion may be predicted with jet type and two-dimensional diffusive, mathematical models provided sufficient experimental data are available to covalidate such models. Selected results are described of surveys conducted on Italian coastal waters employing remote sensing infrared measuring techniques combined with in situ measurements of temperature at different depths with quartz sensors. Based on such experimental data semiempirical models will be established for the prediction of the near field and far field patterns of the thermal plume. Preliminary results of work in progress on mathematical modelling are also presented.

Destefani, R. Handling and Transport of Power Plant Scrubber Sludge Wastes. (Gibbs and Hill, Inc., New York). (1976).

This paper is concerned with the technical and economic factors associated with the need to handle and safely dispose of these large quantities of sludge waste streams. Specific areas which will be considered include: physical and rheological properties of the sludge; selection and evaluation criteria for sludge handling and transport systems and equipment components; special design considerations involved in sludge pipeline systems; and actual data on the design and operation of the Bruce Mansfield Sludge Disposal Facility, currently the largest sludge treatment and disposal facility in the world. Various methods have been developed to handle and treat sludge to produce an environmentally-acceptable product. The Dravo "Synearth" process is one of the most highly developed and commercially available processes.

Dreyhaupt, F.J. Site Selection Planning as a Means of Fulfilling the Principles of Precaution in Environmental Protection. (Ministerium fuer Arbeit, Gesundheit und Soziales des Landes Nordrhein-Westfalen, Duesseeldorf (Germany, F.R.)). (Jan 1977). (In German).

Reasons are discussed for the necessity of long-term site selection planning for energy and area-intensive industrial plants (conformity between environmental policies on the one hand, and policies concerning the economy and the labour market on the other hand). The planning instruments are described: area planning, Laender planning, regional planning, buildings planning. Criteria for site selection planning from the point of view of environmental protection are outlined.

Edwards, R.G.; R.C. Durfee. Geographical Data Structures Supporting Regional Analysis. (Union Carbide Corp., Oak Ridge, Tenn. (USA). Computer Sciences Div.). 1978. p. 7.

In recent years the computer has become a valuable aid in solving regional environmental problems. Over a hundred different geographic information systems have been developed to digitize, store, analyze, and display spatially distributed data. One important aspect of these systems is the data structure (e.g. grids, polygons, segments) used to model the environment being studied. This paper presents eight common geographic data structures and their use in studies of coal resources, power plant siting, population distributions, LANDSAT imagery analysis, and landuse analysis.

Eraslan, A.H.; W. Van Winkle, R.D. Sharp, S.W. Christensen, C.P. Goodyear, R.M. Rish, W. Fulkerson. Computer Simulation Model for the Striped Bass Young-of-the-year Population in the Hudson River. (Oak Ridge National Lab., Tenn. (USA)). Sep 1975. p. 208.

This report presents a daily transient (tidal-averaged), longitudinally one-dimensional (cross-section-averaged) computer simulation model for the assessment of the entrainment and impingement impacts of power plant operations on young-of-the-year populations of the striped bass, *Morone saxatilis*, in the Hudson River.

Ford, A. User's Guide to the BOOM1 Model. (Los Alamos Scientific Lab., N.Mex. (USA)). Aug 1976 p. 59.

This report describes the assumptions and behavior of a computer model designed to simulate the "boom town" impacts of locating large power plants near small, isolated communities. Individual equations and parameter estimates are shown to provide the following information needed to judge BOOM1s usefulness: list of factors not included in the model; causal influence diagrams of vicious circles which act to worsen boom town conditions; flow diagrams in the power plants, housing, public construction and municipal, finance, retail and services, and migration sectors; numerous plots of model variables over a time span encompassing the pre-boom, construction, and operation phases of boom town development; results of tests showing the sensitivity of the model to alternative estimates of parameters; results of illustrative policy simulations showing the effectiveness of front end money, public loan guarantees, and guaranteed loans to the retail and services investor, and list of potential applications of the model by national, state, local, and energy company officials.

Franklin, R.E.; D.S. Ballantine, J.O. Blanton, D.H. Hamilton, C.M. White. Participation of ERDA in the Transport and Ecological Effects Categories of the Pass-Through Program. (Energy Research and Development Administration, Washington, DC). 1976.

Several interagency programs for environmental research are described which ERDA implemented with funds made available through the pass-through program. Some of the projects undertaken deal with land reclamation; offshore oil extraction and related problems; power plant cooling systems; Alaskan oil; and trace contaminants from coal combustion and processing.

Freedman, A.K.; J.C. Cohen. The Environmental Impact of Supplying Power to the Con Edison Service Territory: 1975-1990. (Citizens for Clean Air, Inc., New York (USA)). Aug 1975. p. 160.

A description is given of present and anticipated environmental consequences of meeting electricity demand in the Con Edison service territory--New York City and most of Westchester County. Important issues include nuclear power, air pollution, water and aquatic life, and siting power plants and transmission facilities.

Frigerio, N.A. Power Plant Siting: Evaluation and Optimization. (Argonne National Lab., IL); Gustafson, P.E.; J.M. Cobian. 1975.

In the past, evaluation of plant impact has been done for specific plants located on specific sites, and soon came to include plants still in their planning stages. This effort still constitutes the bulk of the activity at ANL/ESP. Separation of site review from plant review could spare the nation substantial time and effort. Safety and environmental issues could be resolved well in advance and when application for a particular plant was filed for such a site, preparation and limited construction could begin immediately. The ideal would be that the best possible use be made of our resources, with the least possible detrimental impact on our environment. To this end ANL/ESP has devoted much of its effort, in the hope of developing an approach to the future siting of power plants. Simple visual overlays are used, employing color display, three-dimensional display, and rotation techniques.

Gadsby, G.N. Systems Descriptions and Engineering Costs for Solar-Related Technologies. Appendix to Volume I. Experience Curves and Cost Trends: A Preliminary Consideration of Some Factors Likely to Influence Capital Costs in Selected Solar Energy Systems. (Mitre Corp., McLean, VA (USA). METREK Div.). Jun 1977. p. 130.

This Appendix to MITRE/METREK Report MTR-7485 ("System Descriptions and Engineering Costs for Solar-Related Technologies, Volume I") presents the findings of a limited study of experience curve and cost trend histories within a wide range of commodities relevant to projected solar energy system concepts. Two forms of data presentation are used: (1) experience curves derived from production

volume and unit cost inputs and (2) cost trend curves where data on accumulated production volumes are not readily available. Although many years of historical data have been assembled, it has seldom been possible to acquire those relating to the onset of production. However, in the context of the objective of this Appendix, cost trends in relatively recent--say, ten to twenty--years are the more important consideration. Bearing in mind that projected solar energy systems will comprise elements of conventional plant equipment, materials, construction, etc., as well as those unique to such systems, experience curve and/or cost trend histories are presented with respect to the following categories: (1) buildings and structures; (2) construction of complete plant (petroleum refining and processing and electric power generation); (3) component plants and equipments; (4) electric power transmission and distribution; (5) materials; (6) instrumentation and electronics; (7) oceangoing tankers (relevant to OTEC); (8) forest and agricultural products (relevant to biomass); (9) ancillary equipments; (10) labor; and (11) energy.

Gaspar, S.; L. Sine, F. Gorlier. River Water Temperature Assessment Methods Applied to the River Sambre. (Fac des Sci Agron de l'Etat, Gembloux, Belg). (Aug-Sep 1976). (In French).

Theoretical model is presented based on calorific values per unit of horizontal surface, longitudinal dispersion coefficient, and average depth of river. Heat flux is estimated according to means of values and compared with experimental data. Effects of power plants cooling water discharge on temperature fluctuation are considered.

Gaud, W.S.; M.I. Jenness, R.H. Hevly, L. Zaleski, J.R. Davey. Environmental Impact Studies of the Navajo and Kaiparowitz Power Plants. Volume I. Annual Report No. 3, 1 Jun 1973--31 May 1974. (Northern Arizona Univ., Flagstaff (USA)). 1974. p. 390.

During the third year of study, field investigations were concentrated at eight study sites in the vicinity of Page, Arizona. The central purpose of this study was twofold: (1) To determine what effects effluents from power plant operation would have on the ecosystems; and (2) to determine whether those effects would be ecologically significant. A monitoring program was initiated to determine the pattern of changes exhibited by vegetation, by small mammals, by weather, by microbes, and by soil factors. Temperature, humidity, and rainfall seemed to be most variable. A few trends were observed in the vegetation over the past three years, but its high variability probably resulted from the different weather regimes. Changes in the dynamics of small mammal populations were clearer and were synchronized to a large extent in the five communities close to Page. Threshold levels for the destruction of the shrub Ephedra by its insect parasite were determined. Mercury in Lake Powell was found to be more highly concentrated in the bays than in the channels and thresholds for observed effects on diatoms were determined. Baseline trace element concentrations in soil, water, and vegetation were measured.

Gaud, W.S.; D.W. Blinn, D. Czarnecki, R.R. Guerrero, J.S. States.
Environmental Studies of the Kaiparowitz Generating Station:
Supplemental Report. (Northern Arizona Univ., Flagstaff (USA)). 1
Jul. 1974. p. 28.

The purpose of the investigation described was to obtain a baseline of information on: (1) microbial soil communities; (2) aquatic macroinvertebrates; (3) water quality; (4) aquatic habitat; and (5) aquatic primary producers. Microbial studies were carried out in Southern Utah on Fourmile Bench and on Nipple Bench. Aquatic studies were carried out in the drainages into Lake Powell. In addition, available data was obtained on previous assessments of mercury concentrations found in Lake Powell fish. Each vegetation community was characterized by the unique occurrence of particular fungi and by the greater relative frequency and abundance of certain groups of fungi. Average pH values and soil carbonates were higher in soils of the benches than in counterpart soils near Page, Arizona, indicating greater buffering capacity against acid effluent gases. Seeps and springs demonstrated relatively well-developed communities of aquatic invertebrates compared to the low numbers and diversity of the bays. The high number of coliforms was probably related to grazing animals. Diatoms in the drainages were identified and several species also contribute significantly to the phytoplankton of lower Lake Powell.

Gentile, J.H.; J. Cardin, M. Johnson, S. Sosnowski. Power Plants, Chlorine, and Estuaries. (Environmental Protection Agency. Narragansett, R.I.(USA). Environmental Research Lab.). Jun 1976. p. 37.

Results of a year's field investigations at a power plant on upper Narragansett Bay indicated that total residual chlorine at greater than 1.0 ppm was responsible for complete mortality of all pumped phytoplankton and up to 75 percent of the zooplankton. In terms of biological impact, this amounted to approximately 15 tons of primary producer carbon and 1.6 tons of primary consumer carbon from June to December. Biological assay systems using indigenous holoplankton and meroplankton were designed to model the chlorination patterns of power plants. A matrix of chlorine concentrations and exposure times permitted the generation of response isopleths that were then applied to developing design criteria. This data indicated that certain algae species had a 50 percent reduction in photosynthesis at 0.15 ppm after 10 minutes exposure and complete growth inhibition at 0.3 ppm after 5 minutes exposure. Microzooplanktonic adults showed 50 percent mortality after 5 minute exposures to 2.5 ppm total residual chlorine. Furthermore, chlorinated seawater showed residual toxicity to algae, 100 hrs. postdosing, when no detectable residual chlorine was present. Studies of larval and juvenile fish emphasize that short-term exposure to chlorine levels less than 0.2 ppm will produce a significant biological effect under routine intermittent dosage conditions. Laboratory bioassay data was verified in a field study where the researcher was capable

of modifying power plant operations. This study also was used to both develop and verify the use of ATP as a measure of pumped damage to both zooplankton and phytoplankton. The above studies, supplemented by existing data on the toxicity of chlorine to marine organisms, have resulted in a modification of chlorination practices, more stringent effluent guidelines, and revised water quality criteria.

Goerke, H. Commercial Utilization of the Cooling Water of Power Plants. German (FRG) Aug 1975. p. 5. (In German).

It is suggested not to discharge the cooling water of power plants into cooling towers, rivers or lakes, but to use it to heat greenhouses, apartments and other buildings.

Halpern, J.A.; L.D. Alexander, D.M. O'Regan. Application of Remote Sensing Data to Geographic-Based Information Management Systems. (Dames and Moore, Cranford, NJ). 1975.

Remote sensing data are applied to a data management system for a preliminary power plant siting investigation. A siting survey was performed for location of a large power plant facility on the Delmarva Peninsula (Delaware, Maryland, Virginia). The final output of the system is a decision map that reflects all the technical and arbitrary decisions and weights that went into the combining of source data maps. The geologic linear map was constructed by photogeologic interpretation of black-and-white LANDSAT frames in bands 5 and 7 at a scale of 1:500,000. The vegetation map, the land use map, and surface water map were all derived by supervised multispectral processing of digital LANDSAT data.

Hampel, V.E.; R.A. Wiley. Integrating Text and Data for Energy Research. (Univ. of California, Livermore). 1975.

Decreasing energy resources, continuing population growth, and a newly awakened concern about our environment place demands upon the availability of scientific textual information and numeric data. Whatever solutions to the nation's energy problems might be proposed under the aegis of the U.S. Energy Research and Development Administration, they will be highly dependent on reliable, computerized scientific text and data.

Hickley, H.R.; P.A. Krenkel. Measurement and Monitoring. (TVA, Chattanooga). 1976.

TVA's role in the Federal energy research program of measurement and monitoring is described. Activities include: development of methods for chemical analyses of water-borne pollutants, development of improved radiological surveillance programs, and development and demonstration of remote sensing techniques for monitoring environmental effects of power plant emissions.

Horton, R.S.; M.J. Ray, M.L. Buzel, T.J. Hadwin, M.M. Wurmbrand, Search for Future Electric Generating Sites. (New York State Electric and Gas, Binghamton). pp 525-532 of In Energy and the environment. Theodore, L. (ed.). Dayton, OH; American Institute of Chemical Engineers (1976).

Since passage of the National Environmental Policy Act, site selection has shifted emphasis from cost and engineering factors toward equal consideration of environmental values. Although federal and state guidelines require the assessment of impacts associated with power plant development, it is still a matter of judgement which considerations are included in the site selection process. However, recent regulations and opinions stress that environmental considerations be included at the earliest stages of project planning, including the selection of sites. Considering this and the often stringent public review of siting decisions during the licensing process, New York State Electric and Gas decided the best way to select a plant site is to make a comprehensive and detailed study beginning with the entire state and investigating until a small group of very good power plant sites is identified. To do this, a process was developed which reduces the area evaluated at each step while increasing the detail of the evaluations. This continuing thread of refinement and selectivity runs from beginning to end. In this way, the most favorable areas continue to be analyzed, while less desirable areas drop out along the way. This method doesn't guarantee that every good plant site is identified. But other methods don't really guarantee that either. What is assured, though, is that a number of good sites are identified and a consistent method is used to select between them.

Jalbert, J.S.; J.E. Dobson. Cell-Based Land Use Screening Procedure for Regional Siting Analysis. (Oak Ridge National Lab., Tenn (USA)). 3 Oct 1976. p. 99.

An energy facility site-screening methodology which permits the land resource planner to identify candidate siting areas was developed. Through the use of spatial analysis procedures and computer graphics, a selection of candidate areas is obtained. Specific sites then may be selected from among candidate areas for environmental impact analysis. The computerized methodology utilizes a cell-based geographic information system for specifying the suitability of candidate areas for an energy facility. The criteria to be considered may be specified by the user and weighted in terms of importance. Three primary computer programs have been developed. These programs produce thematic maps, proximity calculations, and suitability calculations. Programs are written so as to be transferable to regional planning or regulatory agencies to assist in rational and comprehensive power plant site identification and analysis.

Jellinek, H.H. Osmosis Process for Producing Energy. 31 Aug 1976.
p. 8.

A process is described for generating energy by utilizing the osmotic pressure resulting when two liquids having different chemical potentials are each placed in contact with opposite sides of the same semipermeable membrane. The process is particularly applicable to the production of energy from the system sea water/fresh water. The sea water is in the form of an enclosed body having an outlet orifice in communication therewith. The fresh water passes through the semipermeable membrane causing the osmotic pressure which ejects a stream of salt water through the outlet orifice.

Jiji, L.M.; J. Hoch. Submerged Thermal Discharges. Report No. 101, (City Coll, New York (USA). Dept, of Mechanical Engineering). Aug 1975. p. 98.

Comprehensive analytical solutions to the trajectory, velocity and temperature distribution for various submerged jets are presented. The solutions take into consideration the effect of buoyancy, turbulence, discharge orientation and cross flow. The method of solution is based on an integral-moment technique in which closure is provided by an assumed turbulent Reynolds stress rather than an entrainment coefficient. The validity of this approach was established by comparing results of this theory with exact analytical solutions to laminar jets as well as numerous experimental data on various turbulent discharges. Agreement with experimental results was found to range from fair to excellent. Working charts are presented for a wide range of the Froude number, discharge angle and free stream to outlet velocity parameter.

Jourolman, L.; R.M. Kell, R.C. Jackson, J. Keller. Laws Needed to Expedite Electric Generation Schedules for the Pacific Northwest: Financing, Environmental Laws, and Siting and Licensing Procedures. Volume II. Environmental Laws and Siting and Licensing Procedures. (Kell, Alterman and Runstein, Portland, Oreg. (USA)). 1976.
p. 207.

Volume II of the study examines environmental law as it pertains to the construction of new power plants and the facility licensing process. The following are discussed: legal aspects of the National Environmental Policy Act of 1969, the Clean Air Act Amendments of 1970, the Water Pollution Control Act and the Atomic Energy Act. The present licensing status of new coal-fired and nuclear facilities in the Northwest are reviewed. Recommendations on legislation to expedite the capitalization and construction of new generating facilities in the Northwest are made.

Koenig, L. R.; C.M. Bhumralkar. On Possible Undesirable Atmospheric Effects of Heat Rejection From Large Electric Power Centers. (Rand Corp., Santa Monica, Calif, (USA)). Dec 1974. p. 47.

An assessment is made of potential atmospheric effects that might be caused by the dissipation into the air of waste heat from large electric power generating complexes. The assessment is based on three components: (1) an estimate of the thermal and moisture perturbation on the atmosphere that might be expected from power generating facilities, (2) a search for observations of how nature responds to perturbations of this kind; and (3) interpretation of numerical experiments dealing with atmospheric processes using similar perturbations.

Kohn, H.W.; J.L Kennedy. Power Plant Siting in the United States: A State Regulatory Agency Viewpoint. (Ohio Power Siting Commission, Columbus). pp 25-31 of In Energy for the environment. Rolinskik E.J.(ed.). Dayton, OH; American Inst. of Chemical Engineers (1975).

Eighteen states have now enacted Power Siting statutes. Since they derive from a common source, the 1970 NARUC (National Association of Regulatory Commissioners) guidelines, they uniformly require statements on need, environmental impact, minimum environmental impact, electric systems compatability, conformity with other state regulations, and public service. Of these requirements, need has surfaced as a special problem due to changing economic conditions and growth patterns. The search for a uniform methodology to assess need has examined econometric regression techniques and simulation modeling. Discussion is presented of the salient features of these two techniques, their difficulties, limitations and capabilities. Studies presently under way are aimed at determining underlying causes of the change in the demand curves.

Koenne, W. Net Energy Output of Growing Power Systems. (Oesterreichische Elektrizitaetswirtschafts A.G., Vienna). (Sep 1977). (In German).

By means of a computer model, the relationships between energy consumption and energy output during the construction and operation of individual power stations and (growing) power systems are investigated. The model is of a general nature and can be used for different types of power stations and even mixed systems. A certain construction scheme is presented as a practical example. It shows that statements regarding a negative energy ratio in the case of nuclear power stations lack a concrete basis.

Korp, H.J. Environmental Problems: Another View. (Environmental Protection Agency, Dallas). 1976.

The Environmental Protection Agency is required to administer environmental legislation to control and abate adverse impacts on the environment consistent with the attainment of our other national goals. Its approach is directed toward long-term as well as short-term environmental measures. Carrying out laws passed by Congress, EPA is concerned with the degradation of water supplies, including thermal discharges into water; air pollution; noise problems; solid waste, the need for land reclamation in cases of shallow surface mining; land use itself; and in the nuclear area, the possibility of radiation contamination. These concerns are discussed in detail, but other impacts concerning construction of a new power plant, such as socio-economic factors, are not covered.

Korzeniewski, K.; R. Spiewakowski. Hydrochemical Study of Kamienno and Kwiecko Lakes. Part II. Data of 1971--1972 (after the power station at Zydowo was set in operation). (Higher School of Education, Slupsk, Poland). (1977).

The morphometric conditions of the Kwiecko and Kamienno Lakes have changed after the linking of the two lakes as reservoirs for the power station at Zydowo. Correlations between the water levels, the surface area of the lakes and their volumes were studied at the different variants of the power station work. The violent displacement of the waters in the lakes caused the disappearance of the thermal-oxygen stratifications and the formation of new hydrochemical conditions. Comparison of ion balances from the time before and after the power station was set in operation indicates the inclusion of the substances deposited in the bottom sediments or derived from the flooded areas into the circuit of the circulating matter.

Landgrebe, D.A. The Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana. Semiannual Status Report, 1 Dec 1974--31 May 1975. (Purdue Univ., Lafayette, Ind. (USA)). 31 May 1975. p. 14.

The use of satellite remote sensing for resources management was investigated in Indiana. The technique was applied to strip mining and reclamation, highway planning, and the detection of dolomite reefs. A data base was created and used to produce land characteristics and suitability maps for land use planning. In addition, a three dimensional model was developed which provides a cross-sectional profile of the thermal plumes emitted by point sources of thermal pollution into rivers and lakes; this model may be used for the design and site selection of electric power plants.

Lietzke, M.H. Kinetic Model For Predicting the Composition of Chlorinated Water Discharged From Power Plant Cooling Systems. (Oak Ridge National Lab., Tenn. (USA)). 1 Feb 1977. p. 47.

A kinetic model for predicting the composition of chlorinated water discharged from power plant cooling systems has been developed. The model incorporates the most important chemical reactions that are known to occur when chlorine is added to natural fresh waters. The simultaneous differential equations, which described the rates of these chemical reactions, are solved numerically to give the composition of the water as a function of time. A listing of the computer program is included, along with a description of the input variables. A worked-out example illustrates the application of the program to an actual cooling system. An appendix contains a compilation of the known equilibrium and kinetic data for many of the chemical reactions that might be encountered in chlorinating natural fresh waters.

Loeb, S.; F. Van Hessen, J. Levi, M. Ventura. Osmotic Power Plant. (Ben-Gurion Univ. of the Negiv, Beersheba, Israel). pp. 51-57 of In Eleventh intersociety energy conversion engineering conference. Vol. I. New York; American Institute of Chemical Engineers (1976).

In pressure-retarded osmosis, a liquid permeates through a semipermeable membrane against a hydraulic pressure gradient, i.e., flows "uphill." Hydraulic energy is thus made available because the osmotic pressure (concentration) difference between the two solutions separated by the membrane is greater than the hydraulic pressure difference. Seawater was used as the permeate-donor, the solution having low osmotic and hydraulic pressures. The permeate-receiver, having high osmotic and hydraulic pressures, was a concentrated brine derived from a mixture of the permeate with either Dead Sea brine or solid salt, widely available in surface or underground deposits. Short-term tests were carried out in small hollow fiber permeators to ascertain the permeation flux (volumetric flow rate per unit membrane area). From this information and other data, energy costs were calculated. On the basis of experiments to date, the energy cost is excessive.

Manz, P. Transfrontier Problems in Connection With the Site Selection of Power Stations and Energy Facilities With Environmental Impact. (Kanton Basel-Landschaft, Liestal (Switzerland). Direktion des Inneren; Kanton Basel-Landschaft, Liestal (Switzerland). Sanitaetsdirektion). (Jun 1977). (In German).

This contribution deals with politics and environmental protection, site selection procedures and their consequences, and tasks of international commissions. It concludes that cooperation, research, and agreement are essential for environmental and energy policies which are to be beneficial to all.

Markofsky, M. Preoperational and Operational Hydrothermal Field Data Acquisition and Analysis. (Univ., Karlsruhe, Ger.). (Dec 1976).

Calibration of mathematical models for thermal plume prediction, design considerations, and regulatory requirements provide further motivation for obtaining field data during both the preoperational and operational status of the plant. An analysis of the parameters which are measured during hydrothermal surveys is given. Field techniques examined include calibration of mathematical models for current prediction from measured tide and current patterns; determining dispersion coefficients; developing synoptic temperature patterns from off-boat measurements; and flushing surveys in coastal waters. The consideration of suing operational monitoring of temperature for the evaluation of low induced temperature rises on the order of 1.5°F (0.83°C) yields the conclusion that the operational monitoring should not be aimed at measuring these temperature rises directly but, rather, at verifying that the physical parameters used in the mathematical modeling of hydrothermal conditions were correctly evaluated.

McNulty, K.J.; J.F. McCoy, J.H. Becker, J.R. Ehrenfeld, R.L. Goldsmith. Investigation of Extractive Sampling Interface Parameters. Final Report. (Abcor, Inc., Cambridge, Mass. (USA). Walden Research Div.). Oct 1974. p. 191.

The results are presented of a twelve month, three-phase investigative program with the intent of providing EPA with sufficient information to permit the establishment of minimum specifications for the design of continuous extractive sample interface systems. An extractive sampling interface system is the equipment associated with an instrumental source measurement system which extracts, transports, and conditions a sample of the source effluent. The work was directed toward an investigation of interface systems for use on Category I sources for the following instrumental techniques: (1) non-dispersive infrared analyzers, (2) ultra-violet analyzers, (3) electrochemical sensors, and (4) chemiluminescent analyzers. Both laboratory and field results are reported.

Medicki, H.; M. Kaufman, D.E. Magnus. Design, Development, and Field Test of a Droplet Measuring Device. Final Report, Jun 1973--Jun 1974. (KLD Associates, Inc., Huntington, N.Y. (USA)). Feb 1975. p. 57.

The design, development, and field testing of a concept to measure liquid droplets in the size range from 1 to 600 micrometers are described. The measurement probe is a platinum wire 5 micrometers in diameter. With the probe electrically heated to a predetermined temperature, changes in the probe resistance are related to the size of the impinging droplets in the gas flow. The electrical signals from the probe are processed and used to classify the droplets into six different size ranges or bins. Two prototypes, consisting of the probe and electronic processing unit, were constructed and tested in the field. Actual droplet distributions and concentrations were measured successfully.

Meier, P.M.; T.H. McCoy. Analytical Approach to the Determination of Urban Population Density Gradients and its Application to Energy Planning Problems. (Brookhaven National Lab., Upton, N.Y. (USA)). Oct 1976. p. 65.

Important urban relationships depend on the spatial gradients of population density. Urban population density gradients prove to be important in nuclear energy facility siting, strategic targeting and civil defense, industrial planning, and many varieties of energy planning problems. Following the Introductory Section, Section II turns to a discussion of Clark's hypothesis, which forms the basis for the model of population density to be used in this essay. A method of estimating the parameters of the model is presented in Section III, with an analysis of error sensitivity presented in Section IV. In Section V, the difference between a uniform density specification for a given area and a density gradient formulation, using a calculation of pollutant dose from a centrally located power station as an example is examined. Extension of the model to urban areas of non-circular form is derived in Section VI, again with emphasis on the estimation of model parameters. Section VII presents a comparison of the traditional regression technique for parameter estimation with the numerical method developed in this paper. Finally, in Section VIII; the model is applied to a sample of energy planning problems, the screening of urban areas for suitability for district heating schemes, the computation of transportation costs in the recovery of energy from municipal refuse, and a preliminary formulation of a model of power plant location in urban areas.

Meier, P.M. Linear Programming Model for County-Level Electric Facility Siting. (Brookhaven National Lab., Upton, N.Y. (USA)). Jun 1977. p. 55.

A mathematical programming approach to the disaggregation of regional electric-sector energy scenarios is developed, with particular emphasis on integration with the Brookhaven Regional Energy System Optimization model that defines the regional generation mix, and the Brookhaven atmospheric transport models that allow computation of air quality given emissions at the county level. The model sites generation and transmission facilities by county, in such a way as to satisfy exogenously specified generation constraints at the power pool level. Land use, water resources, and air pollution constraints, as well as cost penalties for various cooling and air-pollution control modes, are included. The objective function can be specified either in terms of costs, or in terms of minimizing emissions subject to fiscal constraints. The model is particularly suited to the evaluation of siting strategy trade-offs, and as a component of integrated environmental-economic analysis of energy-planning.

Metz, W.C. Cooling Ponds, Lakes, and Reservoirs: A Positive Factor in Power Plant Siting. (Westinghouse Electric Corp., Pittsburgh). (Apr 1977).

A specific area of power plant siting now concerns thermal effluents. Some regulations governing these discharges are reviewed. With the EPA now directed to weigh costs and benefits in determining whether a particular level of effluent reduction is economically achievable and reasonable as required by the FWPCA, cooling ponds, lakes, and reservoirs should be reevaluated as alternate methods of power plant cooling. The incremental economic and social benefits that can accrue when cooling ponds, lakes, and reservoirs are made multipurpose are discussed. When a public or private electric utility selects a plant cooling arrangement it bases the judgment on engineering economics, development costs, and environmental and social considerations. Some location characteristics that can influence cooling system choice are: water availability or appropriation problems, topographic features, meteorological influences, and land availability. It has been estimated that the power plants built before the year 2000 will be sited adjacent to water sources in the following proportions: 40 percent, oceans; 30 percent, Great Lakes; 20 percent, artificial cooling ponds; and 10 percent, rivers and lakes. Recreation is not the only incremental benefit which can occur from cooling pond construction. Others under certain circumstances and for a variety of reasons can take the forefront or coexist. Where power plant size, location, engineering costs, area needs and environmental prerequisites dictate other functions (flood control and stream flow augmentation, fish and wildlife use, hydroelectric generation, aquaculture, municipal and industrial water-supply, irrigation, primary and secondary home development area, and/or scenic area) then they too can be accommodated.

Moraw, G.; A. Szeless. Energy Consumption in the Construction and Operation of Power Stations. (Kernkraftwerk-Planungsgesellschaft m.b.H., Vienna (Austria)). (Jul 1976). (In German).

The costs of the principal energy sources (coal, hydro, nuclear (LWR)) in relation to GNP, kW and kWh are compared by a method taking into account the indirect energy consumptions in the construction and operation of the power stations.

Morgan, D.T.; J.P. Davis. High Efficiency Decentralized Electrical Power Generation Utilizing Diesel Engines Coupled With Organic Working Fluid Rankine-Cycle Engines Operating on Diesel Reject Heat. (Thermo Electron Corp., Waltham, MA (USA)). Nov 1974. p. 407.

A comprehensive study of high efficiency electrical power plants, consisting of diesel engines coupled with organic working fluid Rankine-cycle engines (ORCS) operating on the diesel exhaust heat is described. A combined cycle efficiency of 46.3 percent is attained with commercially available diesel engines with a potential for 50 percent using experimental engines. The estimated

unit capital cost of a 50 Mwe diesel/ORCS power plant is \$250/kwe. The use of small power plants is economically feasible, and is a way to reverse the current trend of centralization. Decentralization, coupled with high plant efficiency, would result in important advantages with respect to environmental effects, fuel conservation and effective land use. Conventional diesel and gas engines can be operated on distillate or residual fuel oil, natural gas, and products of coal gasification.

Mott, W.E. Control of Electric Power System Environmental Impacts. (Dept. of Energy, Washington, DC). (Jun 1978).

Murarka, I.P. Model For Predicting Fish Impingement At Cooling Water Intakes. (Argonne National Lab., Ill. (USA)). Jan 1977. p. 53.

A mathematical model has been developed to predict fish impingement at cooling water intakes at power plants. Conceptual development includes the formulation of mathematical functions that relate environmental factors to fish impingement. Although the impingement simulations shown in this report are theoretical, explicit forms of the component functions are being obtained. The model depends on fish behavior, abundance, water flow rates, and the intake structures. Additional work is necessary to obtain parameter values for various fish species and various environmental conditions.

Murphy, A.H.; A. Gilchrist, W. Haefele, G. Kroemer, J. Williams. Impact of Waste Heat Release on Simulated Global Climate. (International Inst. for Applied Systems Analysis, Laxenburg (Austria); Meteorological Office, Bracknell (UK)). Dec 1976. p. 32.

A general circulation model was used to investigate the effects of thermal pollution from large-scale energy parks on climate. Two scenarios, with different locations for the energy parks, were considered. Emphasis was placed on finding an estimate of model variability (on the basis of three control cases), so that the significance of the change caused by the heat release could be evaluated. As far as the model climatology is concerned, significant changes were produced by the energy parks. In addition, the location of the parks influenced the model response. The presently available models do not simulate climate in a completely realistic way so that the results of sensitivity experiments must be interpreted very carefully. At the present stage it can be said that the results call for further investigations.

Nechaev, V.V. Analytical Method For Investigating the Availability of Electric Power Plants. (Jan 1977). (In Russian).

A simplified analytical method of calculating the availability of the main and auxiliary equipment of a power station is presented which uses a mathematical or homogeneous stationary Markov process without dissipative conditions.

Newkirk, R.T. Accurate Simulation of Environmental Impact Over Large Regions. (Univ. of Waterloo, Canada). pp 781-785 of Modeling and Simulation. Volume 8, Part 2. Vogt, W.G.; M.H. Mickle (eds.). Pittsburgh; Instrument Society of America (1977).

Planning optimal locations for major energy-transmission, communications, and processing facilities requires accurate simulation of potential environmental impact over large areas. A generalized simulation system which performs this task is described. A major difficulty resolved is accurate determination of a discrete-valued impact surface over regions with area in excess of 2,000 square miles. An extensive data base is defined and developed. The data base and a set of problem-oriented orthogonal impact factors determine the multicomponent discrete-valued impact surface. An important feature of the simulation is an algorithm to combine multiple ordinal-valued orthogonal factor ratings, taking into account cumulative threshold conditions. Automatic alternate-route selection is performed, and estimated associated impacts presented by both tabular output and computer-generated maps.

Olechowski, T. Method Defining the Necessary Noise Suppressing Levels of the Equipment During the Design of Power Plants and Transformer Stations. (Apr 1977). (In Polish).

An evaluation method of the necessary noise suppressing levels of the equipment of power plants and transformer stations, which can be used to meet the requirements of standards concerning noise protection of the environment, the plant, and station operation and repair is discussed.

Olszewski, M.; G.J. Trezek. Performance Evaluation of an Evaporative Pad Greenhouse System for Utilization of Power Plant Reject Heat. (Univ. of California, Berkeley). (1976).

The overall performance of an evaporative pad greenhouse is considered in terms of the pad heat and mass transfer, the energy budget of the vegetation, and the performance of the power plant. An analytical predictive model for the pad performance was developed utilizing the Merkel total heat approximation. Data obtained from actual greenhouse performance provides an experimental verification of the pad model. Energy balance considerations on the vegetation provide a means of viewing optimal plant growth in terms of the power plant energy dissipation. In general, the results indicate that when an evaporative pad greenhouse system is used for waste heat dispersal, the vegetation can be maintained within its thermal requirement zone, crop irrigation requirements are significantly reduced, and the power plant performance is comparable with conventional closed loop heat rejection systems.

Owens, O.V.H.; P. Dresler, C.C. Crawford, M.A. Tyler, H.H. Seliger.
Phytoplankton Cages for the Measurement in Situ of the Growth
Rates of Mixed Natural Populations. (The Johns Hopkins Univ.,
Baltimore). (Dec 1977).

We have designed and tested phytoplankton "cages" in which captured natural populations can be re-suspended in situ at their original site or at different sites. The "bars" of the cage consist of a membrane whose pores are sufficiently large to permit relatively rapid exchange of "inside" and "outside" nutrient-containing waters which ensures that the contained phytoplankton are always subjected to the "outside" (in situ) nutrient regime. The pores are sufficiently small to retain the captured phytoplankton. In order to measure growth rate precisely the cages are incubated in situ four times greater than the doubling times of the population (ca. 3 days). The population changes within the cages reflect the integral net primary production. Therefore the technique can be used to characterize geographical locations in terms of their potential for supporting the growth of natural phytoplankton populations. A possible specific application of this technique is the comparative study of the effects on the growth of phytoplankton of near field and far field water masses adjoining power plants or sewage treatment plants.

Pacault, P.H. Hybrid Cycle Power Plant With Heat Accumulator for
Storing Heat Exchange Fluid Transferring Heat Between Cycles. (to
Fives-Cail Babcock Societe Anonyme). 17 Aug 1976. p. 10.

An installation for producing motive power, operating on a hybrid cycle of gas and vapor such as steam is described. The installation has a heat accumulator for storing a heat-exchange fluid which can also act as a fluid fuel for a heat source adapted to heat the fluid of the heat accumulator. Heat can be drawn from the accumulator in the form of a flow of hot fluid, for use as required by a motive power producing machine which may be a vapor turbine. Fluid can also be drawn from the accumulator, to act as a fuel for the heat source, supplementary fluid being supplied to the accumulator to make up for the amount drawn off, whereby the accumulator contents are continuously renewed, to reduce thermal decomposition of the fluid fuel. The heat source can be a gas turbine for producing a basic power output, the turbine exhaust gases being used to heat the heat-exchange fluid by way of a heat exchanger connected to the heat accumulator. The installation can be used in a station for generating an electrical power supply for a distribution network with fluctuating power demands.

Poetz, F. Process for Operating a Turbine Plant and Plant for Carrying Out the Process. (to Brown, Boveri und Cie A.G.). German (FRG) 13 May 1976. p. 13. (In German).

The special equipment and process for operating a plant consisting of synchronous machine, gas turbine and compressor improves the equipment protected in a main patent by omitting a previously envisaged expensive clutch. The synchronous machine to be driven as a motor or generator, is solidly coupled on one end to a gas turbine by an over-riding clutch. The gas turbine is stationary. When running to generate electrical power the gas turbine runs with the synchronous generator and, because of the solid coupling, with the compressor on no load. According to this patent this occurs with vacuum operation, by which the no load losses are reduced to 0.2% to 1.8% of turbine output, while in the main patent they lay between 10% and 20% and therefore required a clutch. This vacuum operation of the compressor plant with an absolute pressure before the blades of 0.03 to 0.005 bar and correspondingly low mass flow is made possible by 3 components: A slide in the suction line of the compressor with an adjustable valve in the by-pass; one, or for several compressors, several by-pass lines with adjustable valve between the outlet of the compressor stage and the inlet of the first stage, to produce recirculation; and an adjustable blow-off valve on the pressure side of the compressor and in parallel with the actual pressure line, which leads via a non-return valve to the pressure store. The starting and running positions of these valves are explained in detail for the following modes of operation: generator operation, operation on load and (rare) mixed operation.

Policastro, A.; W. Dunn, R. Paddock. Application, Verification, and Improvement of Numerical Models for Surface Thermal Discharges From Power-Plant Outfalls. (Argonne National Lab., IL). pp 747-762 of In Future energy production systems. Heat and mass transfer processes. Vol. II. Denton, J.C.; Afgan, N.H. (eds.). Washington, DC; Hemisphere Publishing Corp. (1976).

This paper evaluates seven numerical models for the prediction of surface thermal plumes from power plant outfalls in terms of their present and potential capability for environmental impact evaluation. Two of the models discussed are not presently competitive, yet represent interesting approaches. Two other models are from related problem areas and have formulations sufficiently general for future application to surface-discharge problems. The final three models are promising and have already been tested to a limited extent with prototype data. Unfortunately, the comparisons of models to data attempted so far are few in number and have, in general, been poorly executed. The difficulties have typically involved the use of too small a computational grid, the poor choice of turbulence parameters, and the comparison to either incomplete or poor quality data. The models discussed are currently in what might be called the germination stage. Therefore, the above-noted comparisons of model predictions with prototype data, although

not sufficient for final judgments on the models, have aided in identifying major areas of needed work. Recommendations are made for the general improvement of numerical models for surface thermal discharges.

Polyaev, V.M.; N.A. Nikoforov, A.I. Belousov, E.A. Izzheurov. Application of the MR Porous Metal in Sound Absorbing Structures. (Moscow Higher Tech Sch im. N.E. Bauman, USSR). (1977). (In Russian).

Results of an experimental investigation of the sound absorption coefficient of the porous metallic material MR are presented. This material consists of a uniform porous mass obtained by cold pressing of weight-metered extended helical wire. Depending on the initial material, it can be used in the temperature range from 0 to 1800 K and in aggressive media. Products with porosity from 0.10 to 0.95 may be obtained. Porous samples made of wire mark 1*18Ni9Ti with the dia of 0.2 mm, porosity of 0.4; 0.6; 0.8, the thickness of 15; 30; 45; 60 and 75 mm and dia of 30 and 100 mm have been tested. The material shows effective sound absorption in a wide range of frequencies. In this respect it is better than nylon fiber, aluminum felt, technical felt, or asbestos fluff string, but less effective than "vinipor".

Powell, J.R.; F.J. Salzano, W.S. Yu, J.S. Milau. Implications of High Efficiency Power Cycles for Electric Power Generation. (Brookhaven National Lab., Upton, NY). pp 16.1-16.48 of In Frontiers of power technology conference. Stillwater, OK; Oklahoma State Univ. (1975).

A new kind of power conversion cycle, the High Efficiency Power (HEQ) cycle, is described which promises dramatic gains in central power plant power generation efficiency while requiring relatively small development to achieve commercial success. The HEP cycle is similar to the closed Brayton cycle except that a "chemical compressor" replaces the mechanical compressor. In the "chemical compressor" the working fluid, probably hydrogen gas, is chemically absorbed in a metal hydride (e.g., Fe--Ti) particulate bed at approximately 20°C. After saturation the bed is heated to approximately 100°C and the absorbed gas is desorbed at a higher pressure, i.e., turbine inlet pressure. Following cooling of the bed, the absorption/desorption cycle can be repeated. By using a number of beds operating at different parts of the cycle a continuous flow of gas through the turbine can be maintained. The theoretical efficiency of the HEP cycle is calculated. The operation of hydride compressors is described. Potential high temperature and low temperature heat sources for the HEP cycle are discussed. These include power reactors, fossil-fired boilers, solar and geothermal sources, and power plant waste heat. A cost analysis and development requirements for the HEP cycle are presented. It is concluded that a central power station using the HEP cycle can achieve a marginal efficiency of about 60 percent; an HEP addition using waste heat from an existing power plant can add from 25 to 85 percent to total plant capacity; and, with rapid development, commercial HEP units in the MW(e) range could be available by 1985.

Rameus, R.; C. Jolliot. Contribution of the Electricite De France to Air Pollution Control in the Paris Region. (Jan 1975). (In French).

An acid pollution monitoring system installed in Paris and its suburbs around power plants is described. The network is composed of 20 Serec and five Biolafitte model AFG analyzers for continuous pH measurement. The sampling stations are connected to a central computer for data processing and alarm release. The alarm threshold is set at a sulfur dioxide concentration of 600 micrograms/cu m as an hourly mean. At wind speeds below 2 m/sec, the alarm is activated whenever three sampling stations in or around Paris measure concentrations over 600 mg/kg for more than 1 hr. At wind speeds over 2 m/sec, the alarm is released whenever sampling stations in the plume direction have recorded values over 600 micrograms/cu m for more than 1 hr. The alarm notifies the power plants that they are required to reduce their load or to switch over to low-sulfur fuel oil.

Romano, A.J.; J.H. Klein, L. Newman. Air Sampling System to Measure Power Plant Effluents Using a Lightweight Aircraft. (Brookhaven National Lab., Upton, NY). (1975).

An air sampling system to measure power plant effluents from a fixed-wing, light aircraft has been developed and evaluated both in the laboratory and in the field. The sampling system is easily adaptable to a Cessna 206 and provides the capability to measure oxides of sulfur, oxides of nitrogen, particulates and SF₆ tracer gas. Evaluation of the apparatus has indicated that real-time measurements of the conversion of NO to No₂ in the plume at distances up to twenty-five miles are feasible. The oxides of sulfur are measured by a technique employing KOH impregnated filter papers which has been proven to have very high reliability and precision. The applicability, precision, and reliability of the entire sampling system are being evaluated in field operations in St. Louis, Missouri. Results of these tests will be the subject of upcoming papers.

Roy, D.; J. Miffitt, J. Casey, J. Romano, A. Marquis. High Performance Reheat Marine Steam Propulsion Plant Final Report on Phases 1 and 2. (General Electric Co., Lynn, Mass. (USA)). 30 Jun 1977. p. 219.

The engineering studies, design analyses and analytical investigations that were performed to identify, definitize, and develop the design data, engineering details and operational requirements for a high performance marine reheat steam propulsion plant are presented. Special studies were conducted in the following areas: high pressure and intermediate pressure turbine construction, propulsion gear and attached auxiliaries, low pressure and astern turbine construction, turbine control and monitoring equipment, general propulsion plant arrangements, thermodynamics and acquisition cost estimates for major components. This report clearly indicates that a high performance reheat steam propulsion plant is technically feasible and economically justifiable. The need for additional design development of such components as boilers and feed pumps is emphasized.

Quinn, H.B. Jr. Terrestrial Effects of Energy Development on Fish and Wildlife Resources. 1976.

The U.S. Fish and Wildlife Service's effort to improve the rate with which ecological assessments can be made is described. This applied research effort will speed decisions concerning energy development in non-sensitive areas and protect fish and wildlife values by avoidance of critical habitat and more effective reclamation procedures.

Sappo, G.B. Formation of a Local Population of Bream, Abramis Brama Orientalis, in the Heated Water Zone of Konakovo Power Station. (1976).

Ecological and morphological changes are revealed in the bream, Abramis brama orientalis, from various regions. The formation of a local population in the warm water zone of Ivan 'kovo reservoir is discussed. Changes in the structure of the pharyngeal teeth in bream from the zone strongly affected by the warm water discharged from Konakovo power station are recorded.

Sephton, H.H. Renovation of Industrial Inorganic Wastewater by Evaporation With Interface Enhancement. (California Univ., Richmond (USA). Mar 1976. p. 67.

This report evaluates a novel method of increasing the efficiency of an evaporative process to recycle three types of industrial waste waters: power plant cooling tower blowdown, industrial steam generation blowdown, and an acidic mine drainage type of wastewater. The method, known as interface enhancement, involves the addition of a surfactant to the wastewater stream prior to passing the stream through a vertical tube evaporator. For all three waste streams a considerable increase in heat transfer performance was observed. It was concluded that substantial capital and operating cost savings could be realized by modifying existing evaporation systems to accommodate the interface enhancement technique.

Splittgerber, E. Erection and Commissioning of Technical Plants - Process Phases, Risks, Losses. (Allianz Versicherungs-A.G., Muenchen (Germany, F.R.). Abt. Technische Versicherungen). (1976). (In German).

The focal point of the risks involved in the supply and erection of industrial plants changes between the initial settling up of the site and final handing over. That is the subject of this contribution. Various process phases and typical causes of damage are described on the basis of examples. The author elucidates different supply contractual agreements and terms, such as testing period. The effects in the event of loss or damage occurring are demonstrated.

Stassen, J.J. Legislation and Regulations Concerning Air Pollution Prevention: Emission and Immission Standards. (Univ de Liege, Belg). (Oct 1976). (In French).

Survey of noxious substances, standards for analytical procedures, environmental protection against industrial pollution and emission from power plants is given. Activities of the European Community are reviewed regarding permissible levels of pollutants from combustion in cement and limestone plants.

Statt, C. Risk and Risk Acceptance by Society. (Electric Power Research Inst., Palo Alto, Calif. (USA)). 1977. p. 14.

Various dimensions of risk are identified which relate to the manner in which risk is perceived and evaluated and several self-consistent risk characteristics are explored. Factors which are thought to influence the perception of risk include the degree of personal control over the risk, the potential of episodic events, and the probable severity of injury if a risk event occurs. Risk-benefit analysis can be applied to three problems: the allocation of resources for safety expenditures, the setting of standards, and societal risk-taking decisions. Calculations of benefit are needed for the third area of application, methods for the other two frequently do not require such a measure.

Stewart, A.J.; D.W. Blinn, T. Tompkins, S.N. Wilkes. Environmental Impact Studies of the Navajo and Kaiparowits Power Plants. Volume 2. Phytoplankton Population Dynamics in Warm Creek Bay, Lake Powell. Annual Report No. 3, 1 Jun 1973--31 May 1974. (Northern Arizona Univ., Flagstaff (USA)). 31 May 1974. p. 162.

Seasonal and depth distributions of twenty phytoplankton species and selected physio-chemical parameters were followed for a thirteen-month period in the relatively new Lake Powell reservoir. Temperature fluctuations allowed the bay to be classified as a warm monomictic system. The pronounced summer thermocline led to the development of a zone of oxygen depletion. The spring diatom maximum (*fragilaria crotonensis*, *asterionella formosa*) was succeeded almost immediately by a long pulse of *dinobryon sertularia*. Three species of *scenedesmus* showed some temporal and spatial niche differentiation, and *cryptomonas erosa* seemed to be heterotrophic. *Synedra* flourished during the winter months. Multiple correlation analysis suggested that water temperature was a critical algae population regulator. Nitrogen compounds were also implicated although to a lesser extent.

Suffern, J.S. Physical Effects of Entrainment: Current Research at ORNL. (Oak Ridge National Lab., Tenn. (USA)). Aug 1977. p. 36.

An experimental program to evaluate the effects of entrainment on aquatic organisms is being conducted at ORNL. The damage to fish eggs and larvae during entrainment through condenser cooling water systems is one of the major environmental impacts of electric power plants. Studies at operating power plants have indicated that mortality rates can be excessive. These rates may vary among species and between plants. In order to assess the mortality associated with each component of the cooling system, a power plant simulator has been designed and is now under construction. The design of the apparatus is such that the internal hydraulics of an operating power plant condenser cooling system will be effectively reproduced. Experiments will be conducted using fresh water and marine fish species according to the experimental designs described herein. Rearing and holding facilities have been designed and assembled to assure a supply of specimens and allow assessment of delayed mortality. The identification of the factors which cause mortality during entrainment will provide a rational foundation for redesign of the components in cooling systems to minimize environmental impacts.

Tegeder, K. Calculating the Immission From the Emission. (Jul 1977). (In German).

Industrial plants with a large emitted acoustic power (e.g. power plants, isolated chemical plants) may present an acoustic nuisance over a distance of 1,000 m. To prove that limiting values have been kept or detect the noise sources responsible for excess values, sound emission and immission measurements are combined by a sound propagation calculation. Apart from the determination of the level of assessment, there are other results of acoustic plant analysis: The possibility to optimize noise reduction measures and to update the plant with regard to noise emission.

Thoss, R. Possibilities of an Optimum Site Distribution of Power Plants From a General Economic Point of View. (Muenster Univ. (Germany, F.R.). Inst. fuer Siedlungs- und Wohnungswesen). (Jun 1977). (In German).

The paper deals with the optimum spatial distribution of the development potential as a task for town and country planning, the consequences for the energy supply sector, and mentions possibilities for a realization of the optimum site distribution.

Train, R.E. Energy Related Authority. Temporary Suspensions, Compliance Date Extensions, and One Year Postponements for Power Plant Shut Downs; Requirements. (28 Apr 1975).

Proposed changes in the temporary suspensions, compliance date extensions, and one-year postponements for power plant shut-down requirements are announced. The changes affect applicability, some definitions, address of regulatory offices, compliance date extensions, temporary suspension, sources ordered to burn coal which are not eligible to apply or either a compliance date extension or a temporary suspension, petitions by air pollution control agencies, one-year postponement for power plant shutdown, and general requirements.

Voelker, A.H. Power Plant Siting; An Application of the Nominal Group Process Technique. (Oak Ridge National Lab., Tenn. (USA)). 3 Oct 1976.

The application of interactive group processes to the problem of facility siting is examined by this report. Much of the discussion is abstracted from experience gained in applying the Nominal Group Process Technique, an interactive group technique, to the identification and rating of factors important in siting nuclear power plants. Through this experience, interactive group process techniques are shown to facilitate the incorporation of the many diverse factors which play a role in siting. In direct contrast to mathematical optimization, commonly represented as the ultimate siting technique, the Nominal Group Process Technique described allows the incorporation of social, economic, and environmental factors and the quantification of the relative importance of these factors. The report concludes that the application of interactive group process techniques to planning and resource management will affect the consideration of social, economic, and environmental concerns and ultimately lead to more rational and credible siting decisions.

Wohak, B.; G. Meinlschmidt. Information System for Establishing Reliability Data for Power Plant Components. (Technische Univ. Muenchen, Garchnig (Germany, F.R.). Lab. fuer Reaktorregelung und Anlygensicherung). Jun 1976. p. 92. (In German).

The increasing importance of safety and availability of power plant units demands more detailed and proven reliability data for plant components than operational experience could provide till now. In the Federal Republic of Germany an extensive collection of field data from a conventional power plant has been compiled since 1972. By this report the authors present a computer-based information system for the establishment of empirically tested reliability data for power plant components.

Zeni, L. Management Options in Power Plant Siting to Benefit Biological Resources. (Maryland Power Plant Siting Program, Annapolis, MD). pp 309-312 of In Energy for the Environment. Rolinski, E.J. (ed.). Dayton, OH; American Inst. of Chemical Engineers (1975).

Maryland's experience with its Power Plant Siting Law represents a new philosophy in environmental policy management options. This paper deals solely with aquatic resources management and protection in siting power plants in general, on the Potomac in particular. The program provides for enforcement of environmental controls but also imposes responsibility on the program to help utilities to meet those standards and to help competing regulatory agencies consider optimum compromises in meeting regulatory goals.