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ENERGY: USES, SOURCES, ISSUES

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PREFACE

The problems and issues involved in providing our nation with abundant supplies of low cost energy are extremely complex, particularly when we give full attention to minimizing the environment impacts. An immense amount of information has been generated on the subject. This report condenses the data and sets them out in a format designed to emphasize the major points characteristic of the respective problems and issues.

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CONVERSION FACTORS AND ABBREVIATIONS

1 yr = 8760 hr

1 Btu = 778 ft-lb = 1.06×10^{10} erg = 1055 J = 252 cal

1 kWh = 3412 Btu

1 hph = 2545 Btu

1 short ton = 2000 lb

1 metric ton = 1000 kg = 2205 lb

1 long ton = 2240 lb

1 gal = 0.1337 cu ft = 3.785 liters

1 bbl = 42 gal

1 short ton = 2000 lbs

1 bbl crude oil = 5.8×10^6 Btu

1 cu ft natural gas (CH_4) = 1000 Btu

1 ton coal $\approx 24 \times 10^6$ Btu to 28×10^6 Btu

2×10^{12} Btu/yr ≈ 1000 bbl/day of crude oil

^{235}U at 200 MeV/fission releases = 3.2×10^8 Btu/lb

Tcf = Trillion cubic feet (at STP) = 10^{12} cu ft of Natural Gas

Mcf = Thousand cubic feet = 10^3 cu ft

MMcf = Million cubic feet = 10^6 cu ft

1. ENERGY UTILIZATION

IMPLICATIONS OF INDUSTRIALIZATION	1-2
USES OF ENERGY	1-14
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UTILIZATION: IMPLICATIONS OF INDUSTRIALIZATION

- High per-capita total energy consumption is required for high output of goods.
- Economic growth requires abundant energy supplies.
- U.S., Canada, United Kingdom typify nations with a high standard of living.

(Note log scale in the accompanying chart.)

GROSS NATIONAL PRODUCT PER CAPITA VS. TOTAL ENERGY CONSUMPTION PER CAPITA

Data source:

The U.S. Energy Problem, Vol. I

ITC Report C645

InterTechnology Corporation, Warrenton, Va.

November, 1971

UTILIZATION: IMPLICATIONS OF INDUSTRIALIZATION

- High electrical energy consumption per capita is also characteristic of nations with a high standard of living.

(Note log scale of the accompanying chart.)

ELECTRICAL ENERGY CONSUMPTION PER CAPITA VS. GROSS NATIONAL PRODUCT PER CAPITA

Data source:

The U.S. Energy Problem, Vol. I

ITC Report C645

InterTechnology Corporation, Warrenton, Va.

November, 1971

UTILIZATION: IMPLICATIONS OF INDUSTRIALIZATION

- Energy consumption growth in the U.S. exceeds the population growth.
- Energy consumption declined significantly during the mid-thirties. It took a socioeconomic upheaval on the scale of the "Great Depression" to produce this effect. Consumption quickly returned to the pre-Depression growth rate.

ENERGY CONSUMPTION IN THE U.S.

Data sources:

S. Schurr and B. Netschert
 "Energy in the American Economy 1850-1975"
 Resources for the Future, Inc.
 Johns Hopkins Press, Baltimore, Md.
 1960

U.S. Statistical Abstracts, 1971
 (92nd edition)
 U.S. Department of Commerce, Washington, D.C.

UTILIZATION: IMPLICATIONS OF INDUSTRIALIZATION

- Gross national product (GNP) and energy consumption growth rates "track," which implies close interdependence. ("Real" GNP is measured in 1958 dollars.)
- Disposable income growth rate also "tracks," implying that the availability of more dollars for goods and services requires, in turn, more energy for production.

(Disposable income is defined as what people actually have left for saving or spending on consumables after all taxes, corporate savings of undistributed profits, transfer adjustments, and adjustments for consumer interest. Ref: P. A. Samuelson, Economics; New York, McGraw-Hill, 7th edition, 1967.)

ENERGY CONSUMPTION VS. GROWTH PATTERNS IN THE U.S.

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Data source:

U.S. Statistical Abstracts, 1971
(92nd edition)
U.S. Department of Commerce, Washington, D.C.

UTILIZATION: IMPLICATIONS OF INDUSTRIALIZATION

- Dollars spent (\$ spent) = disposable income minus savings.
- Increases in the ratio energy/\$ spent imply a growing demand for services.
- Since 1966, the ratio energy/real GNP has been on the increase, implying that our uses of energy are less productive.
- Also, since 1966, the per capita rate of increase of energy per year has greatly increased.

- Some interesting facts:

In 1969, \$1 of GNP required

1/2 gallon of oil
70 cubic feet of gas
5 pounds of coal.

The cost of energy per \$1 of GNP was

1.6-2.5¢ (industrial use)
7-10¢ (domestic use).

Data source:

U.S. Statistical Abstracts, 1971
(92nd edition)

U.S. Department of Commerce, Washington, D.C.

UTILIZATION: IMPLICATIONS OF INDUSTRIALIZATION

- Before ~1960, the energy consumption per capita yielded a proportionate increase in per capita GNP.
- Since ~1960, this yield in GNP growth has been dropping off, implying that the effectiveness of increases in energy consumption to increase the GNP is diminishing.
- Energy consumption per capita has been increasing faster than the real GNP per capita. This implies also that if we want continued economic growth, our energy consumption per capita must continue to increase.
- We will continue to need abundant energy supplies; that is, the "energy crisis" is a long-term problem.

ENERGY CONSUMPTION VS. U.S. STANDARD OF LIVING

Data source:

U.S. Statistical Abstracts, 1971
(92nd edition)

U.S. Department of Commerce, Washington, D.C.

UTILIZATION: USES OF ENERGY

ONE EXAMPLE OF HOW ELECTRICAL ENERGY IS USED

- Typical load curves in this case illustrate the effects of widespread use of conditioning devices (comfort services) and the increasing use of energy for activities that may not directly affect the GNP.
- The extent to which a new technology can profoundly influence energy utilization is clearly shown. The peak demand is sharply increased and shifted from winter to summer.

TYPICAL LOAD CURVES FOR A MIDWESTERN UTILITY

Data source:

"Potential Nuclear Power Growth Patterns"
Report WASH-1098
Systems Analysis Task Force
Division of Reactor Development and Technology
U.S. Atomic Energy Commission, Washington, D.C.
December, 1970

UTILIZATION: USES OF ENERGY

DISTRIBUTION OF TRANSPORTATION ENERGY

- 74% of transportation energy is consumed by automobiles.
- 57% of auto passenger service is urban (short trip).
- Regulatory means to reduce energy consumption might include:
 - Increasing the use of mass transit
 - Reducing vehicle speed and size
 - Encouraging better utilization of vehicles.

U. S. TRANSPORTATION ENERGY DISTRIBUTION BY MODE (MID-SIXTIES)

Data source:

W. K. Fraize and J. K. Dukowicz
 "Transportation Energy and Environmental Issues"
 Report M72-25
 Mitre Corporation, McLean, Va.
 February, 1972

UTILIZATION: USES OF ENERGY

ENERGY FLOW PATTERNS FOR 1970

- Fossil fuels dominate.
- Electrical output is relatively small ($\approx 8\%$ of the total).
- 25% of the petroleum is imported.
- Transportation uses about half the petroleum and is 96% dependent upon it. All other energy markets can use interchangeable fuels; transportation cannot, because the internal combustion engine dominates.
- Transportation and electrical generation are major contributors to inefficient use of fuels.
- Overall national efficiency in fuel use is about 50%, implying that improvements are needed in:

Conversion efficiency for electrical generation and transportation systems
Better utilization of rejected energy.

- Nonenergy uses are relatively small, but petrochemical feedstocks are very important to the economy.

U. S. ENERGY FLOW PATTERNS, 1970

(NOTE: ALL VALUES ARE $\times 10^{15}$ Btu. TOTAL PRODUCTION $= 71.6 \times 10^{15}$ Btu.)

2. CONSTRAINTS

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CONSTRAINTS: ENERGY COSTS

FOSSIL FUEL COSTS

- Gas prices have been regulated and held low.
- State regulatory agency limits on production and oil import controls have served to allow high oil prices.
- Coal has been unregulated, but the price has remained low because of low convenience.
- Recent price rises of oil and gas are symptomatic of impending shortages.

AVERAGE FOSSIL FUEL PRICES IN THE U. S. AT POINT OF PRODUCTION

Data source:

"Energy: Yesterday-Today-Tomorrow"
El Paso Natural Gas Company, El Paso, Tex.
Summer, 1971

CONSTRAINTS: ENERGY COSTS

GAS PRICE STRUCTURE

- Residential price is high because investment in the distribution system is high and supply is guaranteed to the customer.
- Industrial price is low because the supply is interruptible by agreement.
- Percentage of gas on interruptible contract in the U.S. varies widely from area to area. For instance, in 1970, 60% of California gas was interruptible; only 20% of Illinois gas was interruptible.

U. S. NATURAL GAS PRICES

Data source:

"Energy: Yesterday-Today-Tomorrow"
El Paso Natural Gas Company, El Pasco, Tex.
Summer, 1971

CONSTRAINTS: ENERGY DELIVERY COSTS

- Electrical transmission costs are high.
- Delivery of energy overland is cheapest by pipeline gas and oil. This has tended to encourage the wider use of gas and oil.
- Costs of transporting energy in the form of uranium fuel are negligible.

AVERAGE ENERGY DELIVERY COSTS

Data source:

L. E. Wilkinson
 "Nuclear Energy in the West"
 Western Interstate Nuclear Board, Lakewood, Colo.
 June, 1971

CONSTRAINTS: ENVIRONMENTAL CONSTRAINTS

IMPLICATIONS OF ENVIRONMENTAL CONSTRAINTS

- Near impossibility of producing, transporting, and consuming energy without significant environmental impact.
- Consumer sees gas and electricity as clean energy, but effluents are produced by the total system, elsewhere.
- Pressures for low environmental impact will produce constraints on energy production.
- Constraints will increase prices.
- Serious conflicts are developing among policies to provide clean environment, low cost energy, and abundant supplies to ensure economic growth.

ENVIRONMENTAL CONSTRAINTS ON ENERGY PRODUCTION AND TRANSPORTATION

Problems	Major contributors
1) Air quality <ul style="list-style-type: none"> a) Particulate matter, soot, and fly ash b) Sulfur dioxide c) Unburned hydrocarbons d) Nitrogen oxides e) Carbon monoxide 	<ul style="list-style-type: none"> Industry, power plants Fossil-fuel power plants Motor vehicles Motor vehicles Motor vehicles
2) Water quality <ul style="list-style-type: none"> a) Chemical and mineral wastes b) Acid mine drainage c) Oil spills 	<ul style="list-style-type: none"> Industry Industry Tanker operations
3) Thermal pollution	Power plants
4) Radiation safety and waste disposal	Nuclear power plants (reprocessing plants)
5) Prevention of nuclear accidents	Nuclear power plants (reprocessing plants)
6) Mine safety	Coal mines
7) Strip mine reclamation and surface subsidence	Coal mining operations
8) Solid wastes, garbage	Industry
9) Aesthetics <ul style="list-style-type: none"> a) Facility siting b) Transmission and distribution undergrounding c) Preservation of the wilderness and the Arctic 	<ul style="list-style-type: none"> Power plants Power plants

Data source:

Energy Policy Issues for the United States During the Seventies

Arthur D. Little, Incorporated, Cambridge, Mass.

July, 1971

(Presented at the National Energy Forum, Washington, D. C., September, 1971)

CONSTRAINTS: ENVIRONMENTAL CONSTRAINTS

REACTOR INSTALLATIONS

- Pressures have been mounting against reactor installations despite the fact that radioactive effluents are approximately 1% of natural background.
- Pressure culminated in the Calvert Cliffs decision. Industry spokesmen claim that the decision will cost them \$12.5 billion.
- If the nuclear program is inhibited, energy for electric power must come from coal. The environmental consequences may be more severe.

EFFECT OF CALVERT CLIFFS DECISION ON ELECTRIC UTILITIES

Effect on electric utilities industry
of average one-year delay in
nuclear plant licensing due to
Calvert Cliffs decision

Carrying charge on investments (incremental cost)	\$3 billion
Carrying charge on \$6 billion investment for replacement facilities one year earlier (incremental cost)	\$1 billion
Cost of replacement power in less effi- cient, older facilities (incremental cost)	\$2 billion
Total 1970 capital expenditure	\$12.5 billion
Total capacity affected by delay	91,000 MW
Total current U.S. generating capacity	340,000 MW

Data source

H. M. Winterson
"Nuclear Power: Prospects and Problems"
Atomic Industrial Forum, New York, N. Y.
(Presented at the National Energy Forum, Washington,
D. C., September, 1971)

CONSTRAINTS: ENVIRONMENTAL CONSTRAINTS

AIR POLLUTION

- Transportation activities produce 51% of the air pollutants on a tonnage basis; autos are a major source.
- Industry and power plants together produce 31%.
- Space heating and refuse disposal are minor contributors.
- Fossil-fuel power plants are major contributors of SO₂ effluents.
- Effluent tonnage per year is not a good measure of pollution; the biological impact needs to be quantified.

NATIONWIDE EMISSIONS OF AIR POLLUTANTS BY WEIGHT (1969)

Source	Pollutants - millions of tons per year						%
	Particulates	SO _x	NO _x	UHC	CO	Total	
Transportation	0.8	1.1	11.2	19.8	111.5	144.4	51.4
Fuel combustion in stationary sources	7.2	24.4	10.0	0.9	1.8	44.3	15.7
Industrial processes	14.4	7.5	0.2	5.5	12.0	39.6	14.1
Solid waste disposal	1.4	0.2	0.4	2.0	7.9	11.9	4.2
Miscellaneous*	11.4	0.2	2.0	9.2	18.2	41.0	14.6
Totals	35.2	33.4	23.8	37.4	151.4	281.2	100.0

*Includes forest fires, agricultural burning, structural and coal fires, organic solvent evaporation, and gasoline marketing.

Data source:

"Environmental Quality, 2nd Annual Report"
Council on Environmental Quality
August, 1971
(Republished from Mitre Corporation Report MTR-6013)

**CONSTRAINTS:
CAPITAL AVAILABILITY**

CAPITAL AS A RESOURCE

- Capital investment in energy industries is growing at greatest rate.
- Energy production probably will be limited by capital investment.

PROJECTED CAPITAL INVESTMENT IN THE U. S.

Data sources:

Energy Policy Issues for the United States during the Seventies

Arthur D. Little, Incorporated, Cambridge, Mass.

July, 1971

(Presented at the National Energy Forum, Washington, D.C., September, 1971)

L. M. Olmsted

"22nd Annual Electrical Industry Forecast"

Electrical World

September, 1971

U.S. News and World Report

February 7, 1971

**CONSTRAINTS:
CAPITAL AVAILABILITY**

- Electrical power system development will require the greatest amount of capital.

PROJECTED CAPITAL INVESTMENT IN U. S. ENERGY INDUSTRIES

CONSTRAINTS: CAPITAL AVAILABILITY

CAPITAL FOR ENERGY

- Capital requirements are very high: \$304 billion over next 14 years.
- Oil and gas industry requires \$59 of capital for each \$100 of sales.
- General industry requires \$36 of capital for each \$100 of sales.
- Capital availability is probably the most important constraint on energy availability.

ESTIMATED CAPITAL REQUIREMENTS FOR THE ENERGY INDUSTRY

	Estimated requirements - billions of dollars				
	1970	1985	Cumulative 1971-1985		%
<u>OIL</u>					
Exploration, development, and production	2.8	5.4	64.7	107.0	35
Transportation	?	?	~43.0		
<u>GAS</u>					
Exploration, development, and production	2.0	1.9	27.7	48.7	16
Pipelines	0.4	1.0	9.4		
LNG, LPG	0.2	1.1	11.6		
<u>COAL</u>					
Mines	?	?	9.3	20.0	7
Rail transportation	?	?	~10.0		
<u>URANIUM</u>					
Mining	?	?	2.1	3.6	1
Enrichment, plant improvement, and construction	-	-	1.5		
<u>ELECTRICITY</u>					
Generation	5.6	14.6	124.7	124.7	41
Transportation	2.5	4.7			
Distribution and other	3.6	8.1			
<u>HYDROELECTRICITY</u>					
	?	?	?		-
Total	17.1	36.8		304.0	100

Data source:

U. S. Energy Outlook - An Initial Appraisal 1971-1985, Vol. I
National Petroleum Council, Washington, D. C.
November, 1971

CONSTRAINTS: INDUSTRIALIZATION LEAD TIME

- Transition from one fuel to another in the past has required about 50 years.
- Nuclear energy from fission will emerge soon as a major fuel supply.
- Introduction of new sources (fusion, solar) may require similar time.

ENERGY CONTRIBUTIONS FROM PRINCIPAL SOURCES

Data sources:

S. Schurr and B. Netschert
 "Energy in the American Economy 1850-1975"
 Resources for the Future, Inc.
 Johns Hopkins Press, Baltimore, Md.
 1960

E. W. Cook
 "Flow of Energy in an Industrial Society"
 Scientific American
 September, 1971

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SOURCES: PETROLEUM

PETROLEUM SUPPLY AND DEMAND

- Domestic supply is decreasing.
- Transportation demand alone will exceed the domestic supply by ~1980.
- Additional sources will be needed to meet the demands of other major markets. The current plan is to import oil.
- Production from Alaska is expected to start ~1975, but will not significantly reduce the need for additional oil.
- Cumulative use from 1970 to 1985 will be about 100 billion barrels. Transportation alone will require 60 billion barrels.

U. S. PETROLEUM SUPPLY AND DEMAND (INCLUDING NATURAL GAS LIQUIDS)

Data source:

U.S. Outlook for Energy — An Initial Appraisal 1971-1985, Vol. I
National Petroleum Council, Washington, D.C.
November, 1971

SOURCES: PETROLEUM

PETROLEUM RESERVES

- U.S. will need 100 billion barrels by 1985, but proved domestic reserves are only 39 billion barrels.
- Note that the 1970 production (3.3 billion barrels) just about balanced the 1970 additions to proved reserves in the lower 48 states.
- If Alaskan oil had not been discovered, the proved reserves would have decreased.

OIL RESERVES, PRODUCTION, AND SUPPLY DATA

	Billions of barrels
Proved recoverable reserves as of Dec. 31, 1969	29.6
Additions during 1970 - Lower 48 states	3.0
Alaska	9.7
	12.7
Less: production during 1970	(3.3)
Proved recoverable reserves as of Dec. 31, 1970	39.0

Estimated Potential Reserves

	<u>Lower 48</u>	<u>Alaska</u>	<u>Total</u>
Probable/possible	79	5	84
Speculative	68	20	88
Total	147	25	172

Data source:

"Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada and United States Productive Capacity as of December 30, 1970," Vol. 25
 American Gas Association, American Petroleum Institute, and Canadian Petroleum Association (joint publication)
 May, 1971

**SOURCES:
PETROLEUM**

CUMULATIVE CONSUMPTION OF PETROLEUM

- The lower curve in the accompanying chart represents domestic production. The upper curve includes oil imports.
- Proved recoverable oil reserves (39×10^9 bbls) contain only about 0.23×10^{18} Btu.

U. S. OIL CONSUMPTION

SOURCES: PETROLEUM

- Oil field productive capacity is expected to be reached by 1975.
- Productive capacity is expected to be 10.5 million barrels per day, or 3.05 billion barrels per year. Current domestic production is already approaching this output.
- During past military/political crises, our productive capacity has always exceeded our production.

U. S. CRUDE OIL PRODUCTION AND PRODUCTIVE CAPACITY

Data source:

Hollis Dole

"America's Energy Needs and Resources"

Address presented at Stanford University, Stanford, Calif., January 12, 1971

(U.S. Department of the Interior news release, January 13, 1971)

**SOURCES:
PETROLEUM**

- Number of wells is decreasing.
- Costs are increasing.
- Depth of wells is increasing (not shown).

(Note that gas wells cost more per foot because they are generally deeper.)

OIL AND GAS WELL STATISTICS

Data source:

"Energy: Yesterday-Today-Tomorrow"
 El Paso Natural Gas Company, El Paso, Tex.
 Summer, 1971

**SOURCES:
PETROLEUM**

ACTIVITIES TO INCREASE PETROLEUM SUPPLIES

ALTERNATIVE WAYS TO INCREASE U.S. OIL SUPPLIES

Technique	Potential (billions of barrels)	Comments
Conventional exploration and recovery	Proved U.S. reserves: 39 New fields: unknown	U.S. oil already produced: 93 billion barrels. Exploration is now directed deeper onshore, into deeper water offshore, and into less accessible locations, e.g., Alaska.
Improved recovery methods in discovered oil fields Non-nuclear methods (CO ₂ flood, hydrofrac, etc.) Nuclear stimulation	130-290	Current recovery is about 30% from U.S. oil fields (425 billion barrels originally in place). Recovery might be increased to 60% by improved techniques. U.S.S.R. reports increase from 25% expected in one field to 35% expected after nuclear stimulation.
Heavy oils	100-150	About 10 billion barrels produced by 1965 by methods such as cyclic steam injection, <u>in situ</u> combustion, etc. Calculations indicate a factor of 20-50 improvement in single well recovery by pressure relaxation flow after nuclear stimulation.
Oil shale	2000	Technology exists for surface-mined shale deposits, but no profitable process is yet in operation. Deep-lying deposits are not economic at present. <u>In situ</u> retorting of nuclear chimneys is feasible technically but will not be attractive economically until the processing of fractured regions between adjacent chimneys can be demonstrated.
Coal liquefaction	From strippable coal: 175 From mineable coal: 320	U.S. proved coal reserves: 254 billion tons. U.S. proved strippable coal reserves: 140 billion tons. Coal conversion to oil taken is as 1.25 barrels per ton (COED process).

SOURCES:
GAS

GAS SUPPLY AND DEMAND

- Production in the lower 48 states is expected to fall.
- Other current means of gas production are insufficient to meet the demand.
- Imminent gas shortages are halting new gas uses and causing the conversion of interruptible uses to other fuels.
- Additional sources are needed to meet demands. The possibilities include:
 - Liquid natural gas imports
 - Coal gasification
 - Nuclear stimulation.

U. S. NATURAL GAS DEMAND AND SUPPLY PROJECTIONS

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**SOURCES:
GAS**

GAS RESERVES

- Without Alaskan additions, the proved reserves would have decreased significantly.
- Gas is in very short supply.

GAS RESERVES, PRODUCTION, AND SUPPLY DATA

	Gas volume Tcf
<u>Production/supply data for 1970</u>	
Proved recoverable reserves as of December 31, 1969	275
Additions during 1970 (not including Alaska)	11
Less: production during 1970	<u>(22)</u>
Proved recoverable reserves as of December 31, 1970 (lower 48 states)	264
Alaskan additions during 1970	<u>26</u>
Total proved U.S. reserves as of December 31, 1970	290
<u>Estimated potential supply (existing economic and operating conditions)</u>	
<u>Lower 48 states</u>	
Probable	179
Possible	227
Speculative	<u>207</u>
Subtotal	613
Alaska	<u>327</u>
Total U.S. potential supply	1178
<u>Estimated additional supply through nuclear stimulation</u>	317

Data sources:

"Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada and United States productive capacity as of December 31, 1970," Vol. 25.

American Gas Association, American Petroleum Institute, and Canadian Petroleum Association (joint publication)
May, 1970

"Potential Supply of Natural Gas in the United States as of December 31, 1970"
Potential Gas Committee
Colorado School of Mines Foundation, Incorporated, Golden, Colo.
October, 1971

SOURCES: GAS

CUMULATIVE CONSUMPTION OF GAS

- Projected cumulative demand based on the Future Requirements Committee (FRC) projection corresponds to upper curve. The middle curve corresponds to constant demand, Q_1 . Neither are likely since productive capacity cannot meet these demands.
- Q_2 is expected to be the lower 48 production rate. Consumption at this rate depletes the proved reserves by ~1985.
- Gas from nuclear stimulation can extend the reserves long enough to allow for development of the other potential reserves.
- Contribution from synthetic gas assumes that all strip coal is gasified. Strip coal gasification is not a long-range solution.

(Note the log scale of the accompanying chart.)

U. S. CUMULATIVE GAS CONSUMPTION AND DOMESTIC RESERVES

SOURCES: GAS

ACTIVITIES TO INCREASE GAS SUPPLIES

- For surface-based coal gasification, commercial process are costly. Other schemes are under development.
- In situ coal gasifications could provide as much as 8000 Tcf of gas. Advantages are:
 - Utilizes large, deep coal resources not otherwise recoverable
 - Low capital requirements
 - Low environmental impact.
- In situ process is theoretically sound but R & D are needed to demonstrate practicality.

ALTERNATIVE WAYS TO INCREASE U.S. GAS SUPPLIES

Technique	Potential Quantities, Tcf		Comments
	Proved	Potential	
Conventional exploration			
Onshore	225	613	Exploration is now directed much deeper onshore, into deeper water offshore, and into remote areas.
Offshore	39	238	
Alaska	26	327	
	290	1178	
Imports from Canada	—	?	Canadian proved reserves (53 Tcf) are not available to U.S. Potential discoveries could be large; availability for export to the U.S. will depend on Canadian policy.
Liquefied natural gas imports			
South America	50		1967 proved reserves, not all available for export. Europe and Japan compete with the U.S. for these supplies.
North Africa	135		
Nigeria	4		
Middle East	350		
Synthetic gas			
Naphtha and heavy oil classification		Some	Availability of imported naphtha and heavy oil for this purpose is uncertain. Gasification of naphtha and oil are primarily for meeting peak loads. Sales price will be high, and imported liquids may be subject to import control.
Coal gasification (Surface Processing)		1750	Based on conversion of all the U.S. strippable coal (140 billion tons) to gas at 50% efficiency.
Nuclear stimulation		317	Additional R & D required to prove commercial feasibility.

NOTE: U.S. 1970 consumption was 22 trillion cubic feet (Tcf).

SOURCES:
GAS

COSTS FOR ALTERNATIVE GAS SUPPLIES

Technique	Approximate time scale (years to reach additional 1 Tcf/yr)	Approximate capital investment in billions of dollars needed to reach additional production of 1 Tcf/yr	Gas sales price in dollars per Mcf (1971 dollars)
Conventional exploration			
Onshore	2-3	\$1.5-2	\$0.35-0.45
Offshore	3-5		\$0.50-0.65
Alaska	8-10	Pipeline — \$2	\$0.75-1.00 (Chicago)
Imports from Canadian Arctic	3-5		\$0.75-1.00 (Chicago)
Liquefied natural gas imports	~5	Ships, terminals, storage — ~\$3	\$0.68-1.00 (East Coast)
Synthetic gas			
Naphtha and heavy oil gasification	5-7	10 plants at \$150M = \$1.5	\$0.85-1.60 (Source)
Coal gasification (surface)	~10-15	10 plants and mines = \$2.9	\$0.70-1.00 (Source)
Nuclear stimulation	10	300 wells at \$3.34M = \$1.0 160 wells at \$2.44M = 0.4 \$1.4	\$0.40-0.50 (1976 dollars)

LAWRENCE
LIVERMORE
LABORATORY

**SOURCES:
COAL**

COAL SUPPLY AND DEMAND

- Coal is no longer used for transportation.
- Residential/commercial market for coal is decreasing.
- Coal use for electrical generation is increasing.
- Exports of coking coal are increasing.

U.S. CONSUMPTION OF BITUMINOUS COAL

Market	Consumption - millions of tons		
	1950	1965	1970
Electric utility	88.3	242.7	307.0
Industrial (steam)	114.7	102.0	94.0
Coking coal (steel)	103.8	94.8	107.0
Railroad fuel	61.0	1.2	-
Residential/commercial	84.4	19.0	11.0
Stocks and miscellaneous	38.6	1.8	-
Total U.S. consumption	490.8	461.5	519.0
Export	25.5	51.0	71.0
Total production	516.3	512.5	590.0

Data sources:

U. S. Energy Outlook — An Initial Appraisal 1971-1985, Vol I
 National Petroleum Council, Washington, D. C.
 July, 1971

J. R. Lucas
 "Bituminous Mining and the Electric Utility Market"
Chemical Engineering Progress Symposium Series

**SOURCES:
COAL**

COAL RESERVES

- Total energy content of coal reserves $\approx 83 \times 10^{18}$ Btu.
- Coal is plentiful, but major resources are at depths greater than 1000 feet.
- Current mining methods are not economical at depths greater than 500 feet.
- Need to develop methods for recovering deep coal economically. In situ gasification is a possible solution.

U.S. ESTIMATED COAL RESOURCES

Depth of overburden (feet)	Type of coal	Resources (millions of tons) ^a	Energy reserve (10 ¹⁸ Btu) ^b
100	Strip coal	139,969 ^c	3.56
100-3000	Bituminous	959,290	24.94
	Lignite	447,647	11.64
	Anthracite	12,969	0.34
3000-6000	All types	337,105	8.76
6000-~9000 ^d	All types	1,313,080	34.14
		3,210,060	83.40

^aResources in the ground, about half of which are considered recoverable.

^bConversion factor: 1 ton = 26×10^6 Btu.

^c80% estimated recoverable

^dEstimated depth of overburden

Data source:

"Coal Resources of the United States"
 Geological Survey Bulletin 1275
 U. S. Geological Survey, Washington, D. C.
 January, 1967

**SOURCES:
COAL**

CUMULATIVE CONSUMPTION OF COAL

- Coal reserves are virtually untapped, but most are too deep for economic recovery by conventional methods.
- Strip coal production may have a significant environmental impact. Reforestation and reclamation can be accomplished, but the effectiveness is controversial.

U. S. CUMULATIVE COAL PRODUCTION VS. RESERVES

SOURCES:
COAL

- Most of the low sulfur coal is located in the West.
- Eastern states are high coal users.
- Environmental constraints may require large shipments of Western coal to the East, with accompanying high transportation costs.

PERCENT SULFUR CONTENT OF U. S. COAL RESERVES BY GEOGRAPHIC REGION

Data source :

K. E. Yeager
 "Coal and the Environment"
 Report M71-48
 Mitre Corporation, McLean, Va.
 July, 1971

**SOURCES:
COAL**

COAL PRODUCTION

- Coal mine safety, labor difficulties, capital availability are causing coal production problems.
- Environmental constraints on strip mining are slowing production.

U.S. COAL PRODUCTION DECLINE (1969-1970)

Type of mine	Tonnage (millions)	Tonnage per man-day		Decrease (%)
		1969	1970	
Underground mine	195	16.3	13.7	15.6
Strip mine	265	38.9	33.6	13.8

Data source:

H.S. Richey

"Coal Prospects and Problems"

(Address presented at the National Energy Forum, Washington, D.C., September, 1971)

**SOURCES:
COAL**

ACTIVITIES TO WIDEN USES OF COAL

- **Current activities to widen the uses of coal include:**

SO₂ removal from stack gas

Sulfur removal during burning

Strip mining improvements

Mine mouth usage

Coal gasification

Coal liquefaction.

ALTERNATIVE WAYS TO INCREASE USES OF DOMESTIC COAL

Resource	Quantity (billions of tons)		Comment
	Proved	Potential	
Cumulative past production (thru 1970)	40.8		
1971 production	0.6		
Reserves available for recovery by conventional methods			About 50% of the listed quantities are recover- able by underground mining (about 80% by strip mining).
Strip mining	140	?	Overburden < 100 ft.
Underground mining	<u>254</u>	<u>~210</u>	Overburden < 1000 ft in beds over 28 in. thick.
	394	210	
Currently unrecoverable by conventional mining	1164	1103	Overburden up to 3000 ft, or in beds less than 28 in. thick.
Coal gasification			
Conventional mining and gasification in surface facilities	188 ^a	176 ^a	At 50% coal recovery and 50% conversion, equals 2300 Tcf of gas.
Deep <u>in situ</u> gasification	686 ^b	700 ^b	At 30% coal availability and 80% conversion, equals 7600 Tcf of gas.
Coal liquefaction	188 ^a	176 ^b	At 50% coal recovery and 1.25 bbl/ton (COED Process) equals 225 billion bbl of oil.

^aWestern mineable coal; usable for either gasification or liquefaction (Colorado, Montana, New Mexico, and North and South Dakota, Utah, Wyoming).

^bWestern coals at depths too great for mining.

SOURCES:
COAL

STATUS OF U.S. COAL GASIFICATION PROCESSES AND PLANTS

(Continuous Flow or Fluidized Bed Processes)

Status	Sponsor or company	Date of pilot plant initial operation	Full-scale plant startup	Estimated sale price of gas ¢ /Mcf
<u>Production status</u>				
Lurgi (fixed bed process)	El Paso Natural Gas Co.		1976	90
Naphtha reforming	Algonquin Gas Transmission		Oct. 1973	140
	Brooklyn Union Gas Co.		Fall 1973	130-140
Gas liquids reforming	Consumer Gas Co.	1963 (UK)	Jan. 1973	130-140
	Columbia Gas Co.		Summer 1973	112
<u>Pilot plant status</u>				
BCR super pressure	Bituminous Coal	1973		58
Consol CO ₂ acceptor	OCR/Consolidated Coal	1971		39
Hygas-electrothermal	OCR/Institute of Gas Technology	1970	1977	60
COED-COGAS	OCR/FMC Corp.	1970	1976	75-90 + \$4/bbl
<u>Research status</u>				
Kellogg molten salt	OCR			62
Steam-iron	Fuel Gas Assoc.			50
USBM process	OCR			60

SOURCES:
OIL SHALE AND TAR SANDS

OIL SHALE AND TAR SAND RESOURCES

- About 62% of the oil originally in place is estimated to be ultimately recoverable.
- Oil shale represents the largest resource, although not yet economical to recover.

OIL, OIL SHALE, AND TAR SAND RESOURCES

Commodity	Resources - billions of barrels			
	U.S.	Canada	Middle East	World
<u>Crude Oil</u>				
Original in place	435	44	-	-
Produced to date	93		-	225
Proved available at current prices	39		344	600
Estimated ultimately recoverable	270		780	2,000
<u>Oil Shale (25-100 gal/ton only)</u>				
Original in place ^a	2,000	34	-	5,490
<u>Heavy Oils</u>				
Original in place	150	90	-	-
<u>Tar Sands</u>				
Original in place	18	450	-	-
<u>U.S. Oil and Natural Gas Liquid Consumption</u>				
1966	4.5			
1970	5.4			
1985 (estimated)	9.5			

^aKnown resources only. Total of known and possible resources for the world may be as high as 17,000 billion barrels.

SOURCES: FOSSIL FUEL RESERVES

- As proved oil and gas reserves decrease, recovery of oil and gas from shale and coal will become increasingly important.
- Further exploration on the continental shelves may lead to additional petroleum and gas reserves.
- For comparison:

1970 U.S. total energy consumption $\cong 0.07 \times 10^{18}$ Btu

1970 world total energy consumption $\cong 0.2 \times 10^{18}$ Btu.

ESTIMATED FOSSIL FUEL RESOURCES

Region	Estimated resources—Q(10^{18} Btu) ^a								
	Petroleum liquids ^b		Natural gas ^b		Coal ^c		Shale oil ^d	Heavy oils ^e	Tar sands ^e
	Proved reserves	Total known reserves	Proved reserves	Total known reserves	Proved reserves	Total known reserves			
U. S.	0.27	1.5	0.27	1.5	40	83.4	25.5	0.8	—
Far East	0.11	1.4	0.07	1.1	—	—	0.0	—	—
Canada	0.06	0.7	0.05	0.5	16	37.0	2.1	0.5	2.6
South America	0.19	1.6	0.06	1.2	0.4	0.8	4.6	—	—
Western Europe	0.10	0.14	0.16	0.2	10	21.6	0.1	—	—
Africa	0.41	1.7	0.19	1.4	3	6.2	0.6	—	—
Middle East	2.6	4.2	0.34	3.3	—	—	0.3	—	—
Planned Economies	0.68	3.5	0.56	2.8	120	250.0	0.6	—	—
Total	4.23	14.7	1.7	12.0	189.4	339.0	33.8	1.3	2.6

^aProved reserves data from OGJ, December 1971, pp. 72-73. 1969 consumption: World, 0.175Q; U.S., 0.067Q.

^bExcept for U.S., estimates are from M. K. Hubbert, Resources and Man (1969). Natural gas liquids are added by multiplying oil estimates by 1.2. Estimates for Far East and South America include offshore areas. Natural gas estimates are based on ratio of 6000 cu ft/bbl oil or about 0.95 Btu gas/Btu oil.

^cExcept for U.S., estimates are from Hubbert. Coal in planned economy areas includes only U.S.S.R. deposits. U.S. coal includes all deposits, about 50% considered minable.

^dShale oil estimates from D. C. Duncan and V. E. Swanson, Geological Survey Rept. 523 (1965). Data for U.S. includes only known recoverable resources. Canadian estimate is speculative.

^eData from OGJ, November 1971, pp. 121-136, and U.S. Department of the Interior Rept. IC-8263.

SOURCES: URANIUM

URANIUM RESOURCES

- Huge resources of energy but may be cost sensitive.
- Total energy recovery depends on the development of a successful breeder system. Without this system, energy resources are only 1% of amounts shown.
- Indicated reserves are based on AEC exploration during weapon program buildup. There are probably more undiscovered reserves.

U.S. URANIUM RESOURCES

Price range (dollars per pound)	U ₃ O ₈ resources ^a thousands of short tons			Cumulative energy content 10 ¹⁸ Btu ^b
	Reasonably assured	Estimated additional	Total resources	
5-10	190	325	515	23
10-15	150	200	350	38
15-30	170	440	610	65
30-50	5,000	3,000	8,000	415
50-100	6,000	9,000	15,000	945
100-500	500,000	2,000,000	2,500,000	111,000

^aData based on exploration during 1950's and 1960's.

^b Assumes 70% energy available from ultimate fission of all uranium in a breeder system. If only LWR's are available, the available energy is 1% of these values.

Data source:

E. Edlund and M. Beekman
 "The Status of Nuclear Power and Electric Utilities"
 Special Report NE-14
 Nuclear Engineering Department
 University of Michigan, Ann Arbor, Mich.
 1969

**SOURCES:
URANIUM**

WORLD RESOURCES OF URANIUM (1970)

Price/region	U ₃ O ₈ resources—thousands of tons		
	Reasonably assured	Estimated additional	Total resources
<u>Price to \$10 per pound</u>			
Canada	232	230	462
South Africa	200	15	215
France, Niger, Gabon, C. A. R. ^a	95	81	176
Other ^b	63	49	112
U.S. ^c	390	680	1,070
Subtotal (\$10)	980	1,055	2,035
South West Africa and Australia ^d	100	200	300
Subtotal (\$10)	1,080	1,255	2,335
<u>Price \$10-15 per pound^e</u>			
Canada	130	170	300
South Africa	65	35	100
France, Niger, Gabon, C. A. R.	22	35	57
Other	43	70	113
U.S.	190	360	550
Subtotal (\$10-15)	450	670	1,120
Total less than \$15	1,530	1,925	3,455 ^f

^aCentral African Republic

^bArgentina, Australia, Brazil, Italy, Japan, Mexico, Portugal, Spain

^cAccording to USAEC estimates of January 1, 1971, some 90,000 tons of U₃O₈ may occur as a byproduct of phosphate and copper production through year 2000; 25,000 might be available by 1985.

^dThe task group decided to recognize recent reported discoveries in South West Africa and Australia. In the absence of specific data, the task group arbitrarily added 100,000 reasonably assured and 200,000 estimated additional tons for these discoveries.

^eExcludes reasonably assured 350,000 tons and estimated additional 50,000 tons for Sweden considered to be essentially unavailable because of production limitation and stated Swedish policy of meeting only a "certain part" of Swedish requirements.

^fExcludes reserves in Communist-bloc countries.

Data source:

U.S. Energy Outlook—An Initial Appraisal 1971-1985 Vol. II
National Petroleum Council, Washington D.C.
November, 1971

**SOURCES:
URANIUM**

URANIUM CONSUMPTION

- Without introduction of the breeder reactor, uranium requirements will exceed the total supply of low cost uranium ~2000.

FREE WORLD CUMULATIVE URANIUM REQUIREMENTS

SOURCES: URANIUM

- Without the breeder system, the uranium demand continues to grow.
- Introduction of the breeder system initially requires a higher consumption rate. Maximum demand occurs in the 1990's, then the demand declines.

U. S. ANNUAL URANIUM REQUIREMENTS

Data source :

W. E. Johnson
"The Potential and Problems for Nuclear Power"
U.S. Atomic Energy Commission
(Presented at the National Energy Forum, Washington, D.C., September, 1971)

SOURCES: URANIUM

URANIUM SEPARATIVE CAPACITY

- Additional uranium enrichment capacity is needed during introduction of the breeders.
- If the breeder program develops as planned, the need for a greatly expanded uranium separative capacity will exist for ~30 years. Eventually, the need for separative capacity would decrease to a low level.
- If LWR's are the nation's only reactors, the separative capacity will be insufficient to meet demand.

U. S. ANNUAL SEPARATIVE WORK DEMAND

Data source:

W. E. Johnson
 "The Potential and Problems of Nuclear Power"
 U.S. Atomic Energy Commission
 (Presented at the National Energy Forum, Washington, D.C., September, 1971)

**SOURCES:
URANIUM**

- Even with Cascade Improvement Program (CIP) and Cascade Upgrading Program (CUP), the separative requirements exceed the plant capacity ~1981.
- New plants depend on imminent decision dates.

U. S. CUMULATIVE SEPARATIVE WORK AVAILABILITY * VS. REQUIREMENTS

* Assumptions:

Plutonium recycle (beginning 1974)
Reduced foreign market (5% in 1975 to 35% in 1985)
Tails assay (~0.25% post-1971)

Data source:

W. E. Johnson
"The Potential and Problems of Nuclear Power"
U.S. Atomic Energy Commission
(Presented at the National Energy Forum, Washington, D.C., September, 1971)

SOURCES: WATER POWER

WATER POWER RESOURCES

- Only remaining hydroelectric capacity is 130,000 MWe, but the expected total demand by 1990 is about 1,000,000 MWe.
- Environmental constraints will limit further hydroelectric development.
- New hydropower growth is very unlikely in the U.S.
- Canadian hydropower imports are likely (Canada has some large subarctic hydrosites).

U.S. WATER POWER RESOURCES

Joint Economic Committee

Resources—thousands of kilowatts					Resources—thousands of kilowatts				
State	Developed water power ^a			Est. undeveloped 1967	State	Developed water power ^a			Est. undeveloped 1967
	1950	1960	1967			1950	1960	1967	
United States	18,675 ^b	33,180	45,826	130,444	S. A. - Continued				
N. E.	1,239	1,520	1,491	3,304	Va.	207	416	726	1,276
Maine	391	495	510	1,714	W. Va.	208	208	208	1,994
N. H.	312	445	429	802	N. C.	962	1,220	1,766	919
Vt.	192	199	200	338	S. C.	679	958	1,034	1,315
Mass.	223	227	219	267	Ga.	425	653	1,069	3,197
R. I.	11	3	3	0	Fla.	13	42	39	84
Conn.	107	151	131	183	E. S. C.	2,729	3,750	4,832	3,943
M. A.	1,678	2,472	4,247	4,514	Ky.	271	541	671	1,485
N. Y.	1,225	2,028	3,809	1,292	Tenn.	1,238	1,910	1,804	688
N. J.	9	8	8	241	Ala.	1,220	1,299	2,267	1,630
Pa.	444	436	430	2,981	Miss.	0	0	0	140
E. N. C.	901	929	969	1,256	W. S. C.	466	944	1,698	3,065
Ohio	16	9	2	249	Ark.	148	388	900	915
Ind.	37	31	110	315	La.	0	0	0	76
Ill.	54	42	43	206	Okla.	74	165	363	914
Mich.	399	419	395	272	Tex.	245	391	434	1,160
Wis.	396	427	419	213	Mt.	2,286	4,621	6,083	26,891
W. N. C.	629	1,594	2,734	4,363	Mont.	427	1,235	1,512	6,269
Minn.	181	186	170	157	Idaho	441	1,251	1,251	12,392
Iowa	137	136	136	345	Wyo.	79	189	212	1,286
Mo.	151	293	393	2,025	Colo.	92	253	314	1,875
N. Dak.	0	400	400	195	N. Mex.	25	25	24	154
S. Dak	11	333	1,392	303	Ariz.	541	980	1,879	3,676
Nebr.	142	240	238	1,036	Utah	94	100	208	1,320
Kans.	6	6	5	303	Nev.	587 ^b	587	682	9
S. A.	2,767	3,773	5,349	9,468	Pac.	5,979 ^b	13,578	18,425	73,640
Del.	1	1	0	0	Wash.	2,591	7,002	9,549	23,499
Md.	272	272	494	160	Oreg.	783	2,434	3,449	5,656
D. C.	3	3	3	3	Calif.	2,606	4,054	5,324	11,909
					Alaska	—	67	84	32,511
					Hawaii	—	21	19	35

^aElectric utilities and industrial plants, excluding pumped storage capacity.

^bExcludes Alaska and Hawaii.

Date source:

The Economy, Energy, and Environment
Joint Economic Committee
Congress of the United States
September, 1971

SOURCES: GEOTHERMAL POWER

GEOTHERMAL SOURCES

- Potential may be large.
- Actual energy resource is not known yet.
- Only existing U.S. plant (in Sonoma County, Calif.) has a capacity of 82 MWe. The expected growth is to 7,000 MWe by 1985 in California and Nevada combined.
- If technology permits, the total capacity could be 19,000 MWe by 1985.

POTENTIAL GEOTHERMAL FIELDS IN THE WEST

Data source:

L. E. Wilkinson

Nuclear Energy in the West

Western Interstate Nuclear Board, Lakewood, Colo.

June, 1971

SOURCES: GEOTHERMAL POWER

FEDERAL GEOTHERMAL LAND AVAILABILITY

The Department of the Interior has withdrawn 1,345,670 acres of Federal land from all subsurface use because the acreage is either known to be valuable or is potentially valuable for geothermal-resource development. A state-by-state description of this land was published in the Federal Register on March 24, 1967, and amended on April 2, 1967. It breaks down as follows:

Land known to be valuable (1,052,140 acres)

California	839,640 acres
Idaho	16,000
Montana	17,920
Nevada	38,400
New Mexico	140,180

Land potentially valuable (293,530 acres)

Alaska	65,760 acres
California	83,610
Idaho	7,680
Nevada	81,280
Oregon	34,560
Utah	10,880
Washington	9,760

Ref: Plowshare Geothermal, A Feasibility Study of a Plowshare Geothermal Power Plant, American Oil Shale Corp. and U.S. Atomic Energy Commission, April 1971, p. 3.1

GEOTHERMAL POWER CONSIDERATIONS

Type	Example	Problems
<u>Fluid in reservoir</u>		
"Dry" steam	Lardarello, Italy Geysers, Calif.	Exploration: Few known Water disposal (1 : 5)
Hot water	Wairakei, New Zealand	Water disposal ($\geq 20:1$) Scaling (S_iO_2 deposition)
Hot brine	Baja Calif., Mexico	Water disposal ($>20:1$) Corrosion scaling
<u>Heat in rock</u>		
	None	Low permeability Very large explosives (multimegaton) required to produce permeability. Radioactivity Scaling Ground motion damage to facility Very uneconomic projections
<u>Magma</u>		
	None	Materials problem for plumbing and heat exchange liquid.

SOURCES: ADDITIONAL SOURCES

CONTROLLED THERMONUCLEAR REACTION (CTR)

<u>Fuel</u>	<u>Energy Available</u>
Deuterium	$10^{10} Q (10^{28} \text{ Btu})$
Lithium	$9400 Q (94 \times 10^{20} \text{ Btu})$

SOLAR ENERGY

- Solar flux on atmospheric diametral plane: $5100 Q (51 \times 10^{20} \text{ Btu})/\text{yr}$
- Average flux over U.S. at ground level: $\sim 43 Q (0.43 \times 10^{20} \text{ Btu})/\text{yr}$
- Average usable power density (in U.S. Southwest region): $\sim 0.024 \text{ W}/\text{cm}^2$
- For 1000 MWe power plant:
Collection area $\cong 42 \text{ km}^2 \cong 6.5 \text{ km} \times 6.5 \text{ km}$
- For 10^6 MWe (enough to meet U.S. demand in 1990):
Collection area $\cong 200 \times 200 \text{ km}$
 $\cong 13\%$ of U.S. Southwestern desert

SECONDARY FUELS

- Electrolytic hydrogen from seawater using offpeak or solar power.
- Hydrogen, methane from coal gasification.

4. PROJECTIONS AND ISSUES

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PROJECTIONS AND ISSUES

CHARACTERISTICS OF FORECASTING ENERGY CONSUMPTION

- Estimates vary widely.
- All past projections predicted less energy consumption for 1970 than actually consumed (see accompanying chart).
- National Petroleum Council projection is the latest. They predict a consumption of 125×10^{15} Btu in 1985. Will their estimate also be low?

U. S. ENERGY DEMAND FORECASTS

Data source :

"A Review and Comparison of Selected U.S. Energy Forecasts"
Pacific Northwest Laboratories, Battelle Memorial Institute
December, 1969

PROJECTIONS AND ISSUES

NATIONAL PETROLEUM COUNCIL PROJECTIONS TO 1985

- Domestic gas supply is decreasing.
- Coal use is increasing.
- Nuclear fission is growing rapidly.
- Hydropower contributions are insignificant.
- Oil and gas imports are needed to meet the demands.

U. S. ENERGY BALANCE — INITIAL APPRAISAL

Data source:

U.S. Energy Outlook--An Initial Appraisal, 1971-1985
National Petroleum Council, Washington, D.C.
November, 1971

PROJECTIONS AND ISSUES

- Imports may not always be available because of worldwide competition and/or international politics.
- Countries with the highest populations are experiencing the greatest growth rate in energy consumption.

WORLDWIDE OIL CONSUMPTION FORECAST

Data source

Oil and Gas Journal
November 15, 1971

PROJECTIONS AND ISSUES

ANTICIPATED ENERGY DISTRIBUTION, 1985

- This projection assumes that no radically new technologies either for increasing energy supplies or for more efficient use of energy will be developed in time to have a significant effect by 1985.
- Fossil fuels dominate, and can be used interchangeably except for transportation.
- The transportation market remains 96% dependent on petroleum; this market uses energy very inefficiently, is a major source of air pollution, and the demands are growing. The number of vehicle miles is expected almost to double by 1985. Hence, transportation energy and environmental issues will likely become a major concern.
- Oil imports increase to 50% of oil consumption. Gas shortages cause a drastic reduction in domestic production. Total energy imports are 32% of the total energy consumption.
- How to increase gas supplies is already a major problem in 1972; oil availability will soon be a major problem. Costs of energy from oil and gas will rise.
- Nuclear energy expected to provide ~50% of the energy for electrical generation. If growth is inhibited, the difference must be made up from coal. This may bring economic and environmental dilemmas: safety, labor problems, strip mining, control of plant effluents.
- Overall national energy efficiency drops from ~50% to ~44%. Electrical energy production and transportation are major contributors to inefficient use of fuels.
- Petrochemical feedstocks are very important; but because of dependence on oil imports and competition from transportation, increased costs of products can be expected. Many new petrochemical plants are being built abroad for these reasons.

NOTE

This projection generally agrees with the NPC projection. It includes 0.9×10^{15} Btu of gas from coal gasification, and 0.2×10^{15} Btu of synthetic oil from oil shale. These are not shown as separate items on the flow chart.

U. S. ENERGY FLOW PATTERNS, 1985

LAWRENCE
LIVERMORE
LABORATORY

(ALL VALUES ARE $\times 10^{15}$ BTU—TOTAL PRODUCTION= 122×10^{15} BTU)

PROJECTIONS AND ISSUES

HOW ENERGY WILL BE USED

- Electric power generation is expected to grow at greatest rate.
- Transportation market is the second largest.
- Residential/commercial consumption is mostly for space heating.
- Industrial market includes nonenergy uses of fuels, such as for petrochemical feedstocks.

TOTAL ENERGY CONSUMPTION IN THE U.S. BY MARKET

Data source :

U.S. Outlook for Energy — An Initial Appraisal 1971-1985, Vol. I
 National Petroleum Council, Washington, D.C.
 November, 1971

PROJECTIONS AND ISSUES

ELECTRICAL ENERGY CONSUMPTION PATTERNS

- Greatest growth is occurring in residential/commercial sector.
- Consumption pattern is shifting towards comfort services. This trend may, in part, be responsible for the declining effectiveness of increases in the energy consumption per capita to bring about corresponding increases in the GNP per capita.

U.S. CONSUMPTION OF ELECTRICAL ENERGY

Data source:

"22nd Annual Electrical Forecast"
Electrical World
September 15, 1971

PROJECTIONS AND ISSUES

TRANSPORTATION ENERGY CONSUMPTION PATTERNS

- Autos continue to account for more than 65% of the total petroleum consumption by the transportation industry despite a large growth in aircraft consumption.
- Growth corresponds to an expected doubling of vehicle miles by 1990.

U. S. PETROLEUM CONSUMPTION FOR TRANSPORTATION

Data source:

W. K. Fraize and J. K. Dukowicz
"Transportation Energy and Environmental Issues"
Report M72-25
Mitre Corporation, McLean, Va.
February, 1972

PROJECTIONS AND ISSUES

DEVELOPING U.S. POLICY ISSUES

- Each activity is carried out by a separate agency or commission.
- Conflicting policies and attitudes have developed with respect to:
 - Low cost energy
 - Abundant supplies
 - Environmental issues.
- Nation needs coordinated and consistent policies.
- Dependence on imports has become a major controversy. Chief issues are:
 - Save our resources; buy theirs
 - National security is weakened, and there are serious economic consequences from the dollar outflow.
 - Dependence of the U.S. economy on uncertain foreign oil supplies is a precarious stance.

PROJECTIONS AND ISSUES

ROLE OF FEDERAL AND STATE GOVERNMENTS IN ENERGY

- Federal and State governments have major responsibilities with respect to at least the following:

Regulation of monopoly and preservation of competition

Resource conservation

National security

Taxation

Public lands and access to private lands for public purposes

Preservation of health, safety, and environmental quality

Government research and development.

PROJECTIONS AND ISSUES

MANDATORY OIL IMPORTS PROGRAM

Presidential proclamation 3279 as amended was issued in 1959, to set up the Mandatory Oil Imports program. This proclamation and subsequent analyses, particularly the Cabinet Task Force Report on Oil Imports of February 1970, have provided some definition of the meaning of national security. The Office of Emergency Preparedness Report on Crude Oil and Gas Price Increases of November 1970 summarized the criteria for national security as:

- The need to guarantee supplies sufficient to meet the need of U. S. military forces and defense industries.
- The need for sufficient supply of crude oil and its derivatives to meet essential civilian demands and sustain economic growth.
- The need to foster exploration and development so as to ensure against a depletion of reserves to an extent which would jeopardize the capability of the petroleum industry to meet future demands without undue reliance on foreign sources of questionable reliability.

Ref: Energy Policy Issues for the United States During the Seventies, Arthur D. Little, Incorporated, Cambridge, Mass., July, 1971, p. 60. (Prepared for the National Energy Forum, World Energy Conference, September, 1971.)

APPENDIX A

Transportation Energy and Environmental Issues.	A2
Energy Consumption per Capita and Disposable Income per Capita	A3
Productivity, Energy Consumed per Capita, and Gross National Product per Capita, 1920-1970	A4
Relative Consumption of Major Energy Forms, 1950-1969	A5
Shale Oil Resources of the United States	A6
Shale Oil Resources of the World Land Areas	A7

TRANSPORTATION ENERGY AND ENVIRONMENT ISSUES

Data source:

W. K. Fraize and J. K. Dukowicz,
"Transportation Energy and Environmental Issues"
Report M72-25
Mitre Corporation, McLean, Va.
February, 1972

ENERGY CONSUMPTION PER CAPITA VS. DISPOSABLE INCOME PER CAPITA

Year	Resident Population (000)	Energy consumed		Disposable per capita income (1958 dollars)	Energy consumed per dollar of dis- posable income (thousand Btu)
		Total (trillion Btu)	Per capita (million Btu)		
1955	165,069	39,956	242.1	1,795	134.9
1956	168,088	42,007	249.9	1,839	135.9
1957	171,187	41,922	244.9	1,844	132.8
1958	174,149	42,041	241.4	1,831	130.1
1959	177,135	43,508	245.6	1,881	130.6
1960	179,992	44,960	249.8	1,883	132.7
1961	183,057	45,573	249.0	1,909	130.4
1962	185,890	47,732	256.8	1,968	130.2
1963	188,658	49,649	263.2	2,013	130.6
1964	191,372	51,601	269.6	2,123	126.9
1965	193,815	53,969	278.5	2,235	124.6
1966	195,923	57,130	291.6	2,331	125.1
1967	197,864	59,156	299.0	2,398	124.7
1968	199,870	62,463	312.5	2,480	126.0
1969	201,921	65,912	326.4	2,517	129.7

Data source:

Population data for total energy consumed per capita are from series P-25, No. 450, of the Bureau of the Census. Disposable income data are from Survey of Current Business, U. S. Department of Commerce.

Ref: John N. Nassikas, "An Analysis of the Current Energy Problem," Electrical World Conference "Energy of the Seventies," January, 1971.

PRODUCTIVITY, ENERGY CONSUMED PER CAPITA, AND GROSS NATIONAL PRODUCT PER CAPITA (1920-1970)

Year	Index of productivity ^a (1957-59 = 100)	Energy consumed per capita (million Btu)	GNP per capita (1958 dollars)	Energy consumed per dollar of GNP (thousand Btu)
1920	—	185.8	1315	141.3
1930	—	181.1	1491	121.5
1940	—	180.3	1714	105.2
1950	80.3	224.3	2333	96.1
1955	93.9	242.1	2653	91.3
1956	94.1	249.9	2654	94.1
1957	96.9	244.9	2643	92.6
1958	99.8	241.4	2568	93.9
1959	103.4	245.6	2687	91.4
1960	105.0	249.8	2710	93.3
1961	108.6	249.0	2716	91.7
1962	113.8	256.8	2850	90.0
1963	117.9	263.2	2921	90.0
1964	122.5	269.6	3037	88.6
1965	126.6	278.5	3197	87.4
1966	131.7	291.6	3359	86.8
1967	134.3	299.0	3413	87.7
1968	138.7	312.5	3538	88.4
1969 p.	139.9	326.4	3601	90.6
1970 est.	-	335.0	3500	95.7

^aOutput per man-hour, based on real GNP (1958 prices and hours) of all persons engaged in production in private industry.

Data source:

Data from the Economic Report of the President, February 1970, and Bureau of Mines, except for data prior to 1955 which are from U. S. Energy Policies: An Agenda for Research, Resources for the Future, Inc., 1968, p. 6.

Ref: John N. Nassikas "An Analysis of the Current Energy Problem," presented at the Electrical World Conference "Energy of the Seventies," January, 1971

RELATIVE CONSUMPTION OF MAJOR ENERGY FORMS (1950-1969)

Year	Consumption - % of total						Total gross energy inputs
	Anthracite	Bituminous and lignite	Natural gas (dry)	Petroleum ^a	Hydro- power	Nuclear power	
1950	3.0	34.8	18.0	39.5	4.7	—	100.0
1951	2.6	33.3	19.6	40.2	4.3	—	100.0
1952	2.5	30.0	21.2	41.9	4.4	—	100.0
1953	1.9	29.7	21.6	42.7	4.1	—	100.0
1954	1.9	26.2	23.5	44.3	4.1	—	100.0
1955	1.5	27.8	23.1	43.9	3.7	—	100.0
1956	1.5	27.0	23.4	44.3	3.8	—	100.0
1957	1.3	25.9	24.8	44.3	3.7	0.0	100.0
1958	1.1	22.9	26.2	45.7	4.1	0.0	100.0
1959	1.1	22.1	27.6	45.3	3.9	0.0	100.0
1960	1.0	22.2	28.3	44.6	3.9	0.0	100.0
1961	0.9	21.5	29.0	45.0	3.6	0.0	100.0
1962	0.8	21.3	29.6	44.6	3.7	0.0	100.0
1963	0.7	21.6	29.9	44.2	3.5	0.1	100.0
1964	0.7	21.9	30.2	43.5	3.6	0.1	100.0
1965	0.6	22.3	29.8	43.4	3.8	0.1	100.0
1966	0.5	22.3	30.3	43.2	3.6	0.1	100.0
1967	0.5	21.3	31.0	43.2	3.9	0.1	100.0
1968	0.4	20.9	31.3	43.4	3.8	0.2	100.0
1969	0.3	20.2	32.1	43.1	4.1	0.2	100.0

^aIncludes natural gas liquids

Date source:

1950-1963: U.S. Bureau of Mines Information Circular 8384, p. 60

1964: Minerals Yearbook - 1967

1965-1969: Bureau of Mines, Mineral Industry Surveys, Petroleum Statement.
Annual, December 15 1970, p. 32.

Ref: John N. Nassikas, "An Analysis of the Current Energy Problem," presented at the Electrical World Conference "Energy of the Seventies," January 1971

SHALE OIL RESOURCES OF THE UNITED STATES, IN BILLIONS OF BARRELS

(ne, no estimate. Estimates and totals rounded.)

Deposits	Known resources				Order of magnitude of possible extensions of known resources			Order of magnitude of undiscovered and unappraised resources			Order of magnitude of total resources			
	Recoverable under present conditions	Marginal and submarginal (oil equivalent in deposits)												Oil equivalent in deposits
		10-100	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	
Range in grade (oil yield, in gallons per ton of shale)	10-100	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	5-10	
Green River Formation, Colorado, Utah, and Wyoming	80	520	1,400	2,000	600	1,400	2,000	—	—	—	1,200	2,800	4,000	
Devonian and Mississippian shale, Central and Eastern United States	None	None	200	200	None	800	1,800	—	—	—	—	1,000	2,000	
Marine shale, Alaska	Small	Small	Small	Small	250	200	Large	—	—	—	250	200	Large	
Shale associated with coal	do	do	ne	ne	Small	Large	do	60	250	210	60	250	210	
Other shale deposits	do	do	Small	ne	ne	ne	ne	500	22,000	134,000	500	22,000	134,000	
Total	80	520	1,600	2,200	850	2,400	3,800	560	22,250	134,210	2,010	26,250	140,210	

Data source:

D. C. Duncan and V. C. Swanson, "Organic-Rich Shale of the United States and World Lane Areas, "Geological Survey Circular 523, U.S. Dept. of the Interior, Washington, D. C., 1966.

SHALE OIL RESOURCES OF THE WORLD LAND AREAS, IN BILLIONS OF BARRELS

(ne, no estimate. Estimates and totals rounded)

Continents	Known resources				Order of magnitude of possible extensions of known resources			Order of magnitude of undiscovered and unappraised resources			Order of magnitude of total resources			
	Recoverable under present conditions	Marginal and submarginal (oil equivalent in deposits)												Oil equivalent in deposits
		10-100	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	
Range in grade (oil yield in gallons per ton of shale)	10-100	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	5-10	25-100	10-25	5-10	
Africa	10	90	Small	Small	ne	ne	ne	4,000	80,000	450,000	4,000	80,000	450,000	
Asia	20	70	14	ne	2	3,700	ne	5,400	106,000	586,000	5,500	110,000	590,000	
Australia and New Zealand	Small	Small	1	ne	ne	ne	ne	1,000	20,000	100,000	1,000	20,000	100,000	
Europe	30	40	6	ne	100	200	ne	1,200	26,000	150,000	1,400	26,000	140,000	
North America	80	520	1,600	2,200	900	2,500	4,000	1,500	45,000	254,000	3,000	50,000	260,000	
South America	50	Small	750	ne	ne	3,200	4,000	2,000	36,000	206,000	2,000	40,000	210,000	
Total	190	720	2,400	2,200	1,000	9,600	8,000	15,000	313,000	1,740,000	17,000	325,000	1,750,000	

Data source:

D. C. Duncan and V. E. Swanson, "Organic-Rich Shale of the United States and World Land Areas, "Geological Survey Circular 523, U.S. Dept. of the Interior, Washington, D.C., 1966.

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