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Regional Application of Fossil-Energy Technologies: An Analytical Approach

Final Report

Published—September 1979

Prepared For

U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Planning and Systems Engineering

Under Contract No. EF-76-C-01-2442

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ABSTRACT

Energy supply/demand profiles are presented for the 50 United States and the nine U.S. census regions using 1974 statistics. These profiles include quantity and type of energy reserves, annual primary resource production, and consumption by end-use sector. Each state's and region's energy balance is presented for fossil fuels, quantitatively designating the state or region as a net importer or exporter of these fuels. Finally, the dependence of each consumption sector on each energy source is tabulated.

A major part of the project was devoted to the development of a method for use by energy planners in assessing the effects of policy decisions on energy profiles. A series of energy indices is derived for each census region. The indices are defined to include the effect of consumption of relatively scarce fuels (oil and gas) versus plentiful fuels (coal). The fuel weighting factors, incorporated into the indices, are based upon national depletion rates, i.e., production. The higher the index value, the more critically dependent the particular region and sector are on scarce fossil energy resources. The energy indices technique can be used as a basis for comparisons between consumption sectors in a region, similar sectors in two or more regions, etc.

A number of fossil energy technologies under development at DOE are described. The potential impact of the maturation of these technologies on each census region's energy posture is discussed in conjunction with any regional constraints that may exist.

Finally, a number of sample "what if" scenarios are discussed and the impact of fossil fuel replacements on national, regional and sector energy consumption quantitatively assessed. Calculations associated with the scenarios are described in sufficient detail to permit energy planners to analyze other scenarios of choice.

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EXECUTIVE SUMMARY AND CONCLUSIONS

INTRODUCTION

Each state and region has distinct energy resource, production and consumption characteristics. Hence, different mixes of energy production technologies are required to meet most effectively specific state or regional needs. An analytical tool is required to assist energy planners and decision makers in assessing the probable effects of energy policy on state and regional energy postures.

This report presents a method and approach for selecting fossil energy technologies which can match specific regional characteristics. Thus, the technology's regional application and likely ability to solve identified regional energy problems can be explicitly considered.

METHOD

Supply/Demand Profiles

An energy supply/demand profile has been prepared for each state. The profile contains 1974 data on fossil energy reserves, processing, production, consumption and net foreign and domestic imports and exports for each state. Similar data for each of nine census regions and a summary for the U.S. are also included. The data are summarized in a series of charts.

Energy Indices

Four Energy Indices have been defined which summarize a region's energy consumption and demand characteristics. The indices are defined to include the effect of consumption of relatively scarce fuels (oil and gas) versus plentiful fuels (coal). The fuel weighting factors incorporated into the indices are based upon national depletion rates, i.e., production. The higher the index value, the more critically dependent the particular region and consuming sector are on scarce fossil energy resources. Raw index values can be directly compared. For convenience, the indices are often normalized to an average value of 100. With this normalization it is readily apparent whether a region or sector is above or below the national average in its dependency on scarce fuels.

The Energy Indices are: The Consumption Index, which represents the fuel weighted share of average national energy use for the region or regional sector; the Dependence Index, which represents the weighted fuel

dependence of each region or regional sector; the Population-Induced Consumption Index which represents the consumption sectors and fuels which are likely to be most influenced by population change; and the Industry-Induced Consumption Index, which represents consumption in the industrial and electric utility sectors which is likely to be impacted by industrial development. The energy indices are used to identify critical sectors and regions where more detailed energy impact analyses might be warranted.

Energy Index Matrices

The Energy Index values for the four indices and the nine census regions are displayed in a Summary Energy Index Matrix (Table 1). In addition, Consumption and Dependence Index values are calculated for the transportation, industrial, residential/commercial and electric utility sectors in each of the census regions (Table 2). Each index value is further amplified in a Regional Energy Matrix.

Technology Application Matrices

A Technology Application Matrix compares certain fossil energy technology requirements with regional resources and characteristics. The matrix is used to determine whether a given technology could be applied in a region based upon this comparison.

Seven fossil energy program technologies were selected for analysis: High Btu Gasification, Low Btu Gasification, Direct Combustion, Advanced Power Systems, Coal Liquefaction, Gas and Oil Extraction, and Oil Shale. The output products are listed for each fossil technology along with the resource requirements and the major problems or constraints.

Technology Index symbols are placed on the matrix to indicate which technologies can be applied in each region. A filled circle (o) in this Technology Index column indicates that the technology would be applicable within the region, assuming that present technological constraints can be overcome. When there are some regional constraints, that can be resolved, a partially filled circle (o) symbol is used. If the technology has prohibitive regional constraints, it is considered not applicable (N/A).

TABLE 1
ENERGY INDEX MATRIX

<u>REGION</u>	<u>CONSUMPTION INDEX</u>	<u>DEPENDENCE INDEX</u>	<u>POPULATION INDUCED CONSUMPTION INDEX</u>	<u>INDUSTRY INDUCED CONSUMPTION INDEX</u>
NEW ENGLAND	45	121	57	22
MIDDLE ATLANTIC	122	96	147	74
SOUTH ATLANTIC	112	93	124	87
EAST NORTH CENTRAL	157	87	167	128
EAST SOUTH CENTRAL	46	77	46	41
WEST NORTH CENTRAL	73	104	81	52
WEST SOUTH CENTRAL	198	128	118	368
MOUNTAIN	46	93	46	42
PACIFIC	101	100	109	87
U.S.	100	100	100	100

SOURCE: SCI Calculations from 1974 Supply/Demand Profiles

TABLE 2

SUMMARY OF SECTOR CONSUMPTION ANDDEPENDENCE INDEX VALUESCONSUMPTION INDEX

	<u>TOTAL</u>	<u>TRANS</u>	<u>INDUS</u>	<u>R/C</u>	<u>ELEC</u>
NE	45	54	16	74	35
MA	122	165	62	188	75
SA	112	191	78	87	90
ENC	157	211	144	236	34
ESC	46	87	45	42	11
WNC	73	110	54	98	29
WSC	198	169	394	76	152
M	46	70	45	46	21
P	101	170	85	87	59

DEPENDENCE INDEX

	<u>TOTAL</u>	<u>TRANS</u>	<u>INDUS</u>	<u>R/C</u>	<u>ELEC</u>
NE	121	132	129	132	91
MA	96	132	63	131	55
SA	193	132	90	127	50
ENC	87	132	77	128	18
ESC	77	132	83	127	12
WNC	104	132	112	129	40
WSC	128	132	129	130	120
M	93	132	110	128	32
P	100	132	123	130	44

SOURCE: SCI Calculations

The Technology Indices for all regions are summarized in a Summary Fossil Energy Technology Index Matrix (Figure 1) which lists the technologies on one axis and the regions on the other axis. The sizes of the index circles are representative of the maximum potential impact of a given technology within a particular region.

REGIONAL ENERGY ANALYSIS

The U.S. and each of the nine regions were analyzed using the Energy Index values and the Energy Index Matrices.

The West South Central region is the largest consumer of critical fuels and has the highest Consumption Index value. The East North Central region is the largest total energy consumer but, because the region consumes a substantial amount of less critical coal, the Consumption Index value is less than that of the West South Central region. The Middle Atlantic region is also a large consumer of critical fuels. The East South Central, Mountain and New England regions have almost equally the lowest Consumption Index values.

The West South Central is also the region with the greatest dependence on critical energy fuels, having the highest Dependence Index value. Even though the New England region was one of the lowest consumers of energy, the region is second highest in its dependency on critical fuels. The East South Central is the region with the lowest dependency on critical fuels. The East North Central region has the second lowest Dependence Index value, despite the fact that it is a major consumer of critical fuels. The reason for this is the East North Central region's relatively large dependence on coal, a less critical energy fuel.

The greatest energy reserve base of any region is within the Mountain region, with its vast reserves of coal and shale. The region with the second largest reserves is the East North Central. All other regions have significantly smaller reserves, including the oil and gas rich West South Central region. This is due to the much greater national coal reserves compared to national oil and gas reserves.

An analysis of the Energy Index values and Energy Index Matrices is presented in Chapter III. The results include some conclusions on how the index values could be reduced in critical regions. These conclusions are

FIGURE 1.
TECHNOLOGY APPLICATION INDEX MATRIX

REGION TECHNOLOGY	NEW ENGLAND	MID ATLANTIC	SOUTH ATLANTIC	EAST NORTH CENTRAL	EAST SOUTH CENTRAL	WEST NORTH CENTRAL	WEST SOUTH CENTRAL	MOUNTAIN	PACIFIC
HIG- BTU GASIFICATION	○ N/A	●	●	●	●	●	◐	●	◐
LOW BTU GASIFICATION	◐	●	●	●	●	●	◐	●	◐
DIRECT COMBUSTION	◐	●	●	●	●	●	◐	●	◐
ADVANCED POWER SYSTEM	◐	●	●	●	●	●	◐	●	◐
COAL LIQUEFACTION	○ N/A	●	●	●	●	●	◐	●	◐
GAS & OIL EXTRACTION	◐	●	◐	◐	◐	●	●	●	●
OIL SHALE	○ N/A	○ N/A	○ N/A	○ N/A	○ N/A	○ N/A	○ N/A	●	○ N/A

LEGEND:

TECHNOLOGY COMPATIBILITY

- — APPLICABLE
- ◐ — SOME REGIONAL CONSTRAINTS
- — NOT APPLICABLE

MAXIMUM POTENTIAL IMPACT

NOTE: SEE TEXT FOR FULL EXPLANATION OF SYMBOLS SOURCE: SCI

based on regional index value observations and comparisons and reflect the manner in which some regions are able to maintain low Energy Index values while other regions have high values and may be approaching a critical energy situation. In order to reduce energy dependence on critical fuels and lower index values a region could:

- o Convert the electric power sector to use of coal or nuclear fuel
- o Convert the industrial sector to use of coal
- o Reduce residential/commercial dependency on oil and gas by conservation or by encouraging the use of electricity generated by coal or nuclear fuel
- o Reduce the high consumption of oil in the transportation sector through conservation
- o Encourage production of currently undeveloped coal and oil shale reserves.

FOSSIL ENERGY TECHNOLOGY ANALYSIS

An analysis of the regional applicability of the seven fossil energy technologies, noted above, reveals the following:

- o Direct Combustion is applicable in all regions except the New England, the West South Central and the Pacific because in these regions coal transportation is considered a severe constraint.
- o Low Btu Coal Gasification is applicable in the same regions as Direct Combustion for similar reasons.
- o High Btu Coal Gasification is applicable in the six regions that produce coal and can support the other process requirements. The product of this technology, however, can be exported to other regions. High Btu gasification is not applicable in the New England region which does not have sufficient coal. It could only be applied in the West South Central and Pacific regions if regional transportation facility constraints are overcome.
- o Gas and Oil Extraction technology can be applied in the Middle Atlantic region where offshore reserves are adequate for production. The technology also can be applied in the New England and South Atlantic regions if offshore reserves prove to be adequate. Enhanced Oil and Gas Recovery techniques will help to increase supplies in the regions currently producing significant amounts of oil and gas, such as the West South Central, the Mountain, the Pacific and the West North Central regions. Secondary and tertiary Enhanced Recovery techniques could be

applied in the East North Central and East South Central regions, but would not have a large impact because reserves are not abundant. Increased production could be exported to other regions.

- o Oil Shale technology is directly applicable only in the Mountain region and represents a large potential if the economic cost is favorable and the environmental impact is not severe. Development of appropriate transportation systems could allow the introduction of oil shale products into other regions.
- o Advanced Power Systems have potential for producing electricity more effectively. The technology could be applied in all regions except the New England, the West South Central and the Pacific regions because of regional transportation and/or water constraints.
- o Coal Liquefaction can be applied in those regions that have coal resources if the technical problems of solid-liquid separation are resolved and the economics are favorable. This technology would not be applicable in the New England region because of the lack of coal and the difficulty of transporting large amounts of coal into the region. The small reserves and production of coal in the West South Central and Pacific regions limit the application of Coal Liquefaction in those regions. Coal liquefaction products can be exported to other regions.

ALTERNATIVE SCENARIO IMPACT ANALYSIS

The application of the Energy Indices in delineating the relative criticality of regional and end-use sector utilization of energy has already been described. To further demonstrate the versatility of these indices, a number of sample "what if" scenarios are discussed, including:

1. Substitution of low Btu gas for natural gas in the East North Central industrial sector
2. Conversion of electric utility plants from oil and gas to coal in three regions
3. Replacement of gasoline engines in cars with diesel engines
4. Substitution of coal for oil and natural gas in manufacturing industries
5. Reconversion of electric power plants, which had switched to oil and natural gas in the last 10 years, to coal.

Calculations associated with the scenarios are described in sufficient detail to permit energy planners to analyze other scenarios of choice. The first scenario is discussed below as an illustration of the utility of the technique.

Sample Scenario Description

This scenario involves the introduction of a Low Btu Gasification technology into the East North Central Region and is based on the following assumptions.

As of January 1974, 11 low Btu gasification plants are on-line and in full production. At the same time, coal production within the region has been increased to meet the requirements of the gasification plants. The quantity of gas produced by 11 plants results in approximately 1 quad of energy per year for use within the region. The 11 plants consume approximately 1.4 quads of coal per year. The low Btu gas taken from this coal is used for industrial process heat as a substitute for natural gas. The substitution of the low Btu gas for natural results in a reduction of natural gas imports into the region. Under the assumptions of the scenario there is a corresponding decrease in the national production of natural gas; therefore the depletion rate of this resource has been lowered and the relative weights of energy fuels have changed.

Scenario Analysis

The weighted Energy Index values computed for the East North Central industrial sector show that there has been about a 50 percent drop in this sector's Dependence and Consumption Index values. This change occurs even though the sector consumes an additional 0.4 quad of energy with the introduction of the coal gasification technology. The reduction in criticality is due to the substitution of a plentiful fuel, coal, for a less abundant one, natural gas, and is a good measure of how effective such a change would be. Obviously, if this coal-based technology could have been implemented in 1974, as described above, the region's industrial sector would not have been as hard hit by the subsequent natural gas shortage.

The U.S. Total Energy Index figures indicate the magnitude and the importance of the ENC industrial sector in determining the nation's industry demand profile. The impact of replacing natural gas with coal in this one regional sector results in a 10 percent decrease in the critical use of rapidly depleting resources by the nation's industry. Attendant decreases in total U.S. consumption and dependence indices are about four percent.

Energy Impact Analysis Conclusions

One objective of this report was to demonstrate an easily understood method based on index numbers resulting from simple calculations, that could be used to determine the relative criticality of energy supply/demand regions and sectors for a variety of scenarios. The approach developed appears to meet this objective.

Given the available data, index values can be determined for states, counties within states, and even specific metropolitan areas, with the U.S., a region, or a particular state used as the base value. End-use sectors may be subdivided to determine critical sector components, such as particular industries. The method can be used in conjunction with projections for future years. It could also be used to determine which technologies or combination of technologies would have the greatest impact on critical energy consumption within a region or sector.

In addition, the Energy Indices may be used as a planning tool for prioritizing the development of energy related technologies. In the present method the Energy Index Matrices help to define the various regions' energy criticalities. After describing the energy situation and which regions are approaching critical energy problems, the Fossil Energy Technology Matrix and the Energy Technology Indices indicate which technologies can be applied to solve these energy problems based upon each region's energy demand/supply situation, its physical characteristics and its environmental constraints. A more advanced integration of the Energy Matrices with the Technology Matrices would be to assign numerical values to selected technology criteria and to sum the values for each technology. The resulting numerical Technology Indices would be weighted in relation to the Energy Index values. The result would be a method for selecting technologies that are best suited to a specific region and the selection of a particular technology that should be given the highest priority for development in that region. Alternately, this method would allow for selection of the most appropriate regions for the introduction of any specific technology.

This impact analysis demonstrates the potential utility of the method. Its relevance is that it can be used to quantitatively evaluate proposed courses of action in relation to specific national, regional, or state energy goals and objectives.

I. INTRODUCTION

In January 1977, a report by Systems Consultants, Inc. (SCI), "The Application of Near-Term Fossil Technologies to the Energy Supply/Demand Profiles of U.S. States and Regions" (FE/2442), was published. The report summarized the development of an analytical method and presented a series of matrices which matched the state and regional energy supply/demand data profiles with near-term fossil technologies.

This report supplements the original SCI report. The energy data base is updated and improvement made in showing the relationship between given fossil energy technologies and specific regional characteristics. Specifically, this report:

- o Updates the state and regional supply/demand profiles using 1974 data
- o Develops indices to identify and quantify critical regional energy characteristics
- o Quantifies the impacts of Fossil Energy technologies to allow comparisons between technology requirements and regional resources
- o Develops a method to relate Fossil Energy technologies to specific regional energy problems
- o Carries out specific analyses using reasonable scenarios to demonstrate the method.

One of the difficulties in energy policy analysis has been the absence of a clear but sensitive method for analyzing the mix and amount of energy fuels consumed on both a national and regional basis. The thrust of this report is to offer a method which has both the flexibility and completeness to provide national as well as more detailed energy analyses. A major component of this project was the design and exposition of a method which provides a basic tool for energy analysis. It applies equally well to present or projected energy consumption patterns. Chapter II explains this method and the data base which is used to test it. Chapter III applies the method to energy consumption in 1974, including some of the more significant regional energy consuming sectors in the nation, in order to identify which fossil energy technologies will be best suited to reduce critical fuel consumption in those key energy sectors. Also, a detailed analysis of the energy characteristics of each of the nine census regions^{1/} is

presented in Chapter III. Regional resources and fossil technology requirements are compared and analyzed for each consumption sector of the nine regions. Conclusions are presented concerning the most applicable fossil energy technologies to reduce regional oil and gas dependence.

In Chapter IV a series of "what if" energy scenarios is described and the method applied to each. Seven scenarios are described which cover different possible energy situations or problems. Four of the seven scenarios are worked through entirely with analyses of results included.

Chapter V concludes with a summary of the usefulness of the method for analysis and decision making. Additionally, the chapter includes recommendations concerning the method and its broader applications.

^{1/}An alternative analysis was performed using different regionalization schemes. It was determined that no single regionalization of states would satisfactorily group states by energy demand or supply characteristics. The conclusion of the analysis was to continue with the defined census regions so that energy data from this report could be compared with data from the previous report. It is recommended that future analysis be done on a state-by-state basis to avoid the regionalization problem.

II. DESCRIPTION OF THE METHOD AND APPLICATION TO ENERGY CONSUMPTION PATTERNS

A major objective of this project was the development of improved methods to identify and scale regional energy characteristics. Toward this end, a set of Energy Indices has been devised. An important property of the index values is that they are sensitive to the mix, amount and scarcity of energy fuels consumed. The indices can be used for comparisons among geographical regions or consumption sectors. A second objective was to compare the requirements of fossil energy technologies under development at DOE with regional resources. A third objective was to develop a method which relates fossil technologies to specific regional energy problems. Two approaches are developed in this chapter which provide an analytical basis for relating fossil energy technologies to specific regional energy problems.

Section A describes the energy data base, its sources and format, and lists appropriate conversion factors. In Section B the Energy Indices are defined, sample calculations of the Indices presented, and the properties of the Indices discussed. In Section C comparisons among energy indices are made and various regions and consuming sectors with above or below national average characteristics are identified by means of the Indices. Section D discusses the data base for the fossil energy technologies and regional resources, and describes the two approaches for applying the fossil energy technologies to ameliorate regional energy problems. Examples of the method are given throughout the chapter.

A. THE ENERGY DATA BASE

The basic source for the energy supply and demand data is the Energy Information Administration (formerly the U.S. Bureau of Mines). Data are from 1974, the latest published data available on a state-by-state basis (1).^{1/}

^{1/}Numbers in parentheses refer to publications listed in the Bibliography, Chapter VI.

The quantity and location of reserves of uranium and oil shale were obtained from other sources (2)(3).^{2/}

Energy data in this report have been arranged in Energy Supply/Demand Profiles. The Profiles facilitate review and analysis of both supply and demand energy data for each state or region. An example of an Energy Supply/Demand Profile is presented in Table 3 for the East North Central Region (Illinois, Indiana, Michigan, Ohio and Wisconsin). A U.S. Summary Profile (Table 4), following the same format, provides U.S. total energy data including undistributed items. The nine census regions are displayed on a map in Figure 2, and a summary of the regional Profiles is provided in Table 5. For reference, the states in each region are listed in Table 6. Profiles for all states and regions are detailed in Chapter III.

The following discussion reviews the basis for the development of the U.S. state and regional Energy Supply/Demand Profiles and describes the implications and problems associated with interpreting the data on a regional or state basis. Items presented in the profiles are discussed below.

Energy Reserves

The reserves section indicates the demonstrated coal reserve base and the quantity of known, recoverable energy reserves of oil, natural gas, uranium oxide, U_3O_8 (at costs up to \$30 per pound) and oil shale (with more than 25 gallons of oil per ton) that exist within a given state or region. The amount of coal that can be recovered from a deposit ranges from 50 to 90 percent of a reserve base.

^{2/}Reserves of uranium (U_3O_8) are included in reference (1), but are based on amounts recoverable at a cost of \$15 per pound or less. It was believed that reserves based on a \$30 per pound recovery cost were more realistic and therefore reference (2) was used instead. Estimates of oil shale reserves were based upon known resources exceeding 25 gallons per ton yield.

**FIGURE 2. REGIONAL DIVISIONS
OF THE UNITED STATES**

TABLE 5. REGIONAL SUPPLY/DEMAND PROFILE

CHARACTERISTICS REGION	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																NET IMPORTS (FOREIGN & DOMESTIC)						
	COAL 10 ¹² TONS	OIL 10 ¹² BARRELS	GAS 10 ¹² CU.FT.	URANIUM 10 ³ LBS.	OIL SHALE 10 ¹² TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ¹² TONS	OIL 10 ¹² BARRELS	GAS 10 ¹² CU.FT.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP
NEW ENGLAND	0	0	0	0	0	2	0	FOSSIL 137	0	0	0	4,753	16,912	218.3	COAL	—	5.3	—	46.7	1.6	54.3	—	10	1	—	3	100%	—	2	0	6	78	2	54.3	2290.3	267.4	2612.0
								NUCLEAR 6							OIL	782.5	181.3	860.8	461.9	3.8	2290.3	34	8	38	20	0	100%	100	57	70	63	72	81				
	0	0	0	0	0			HYDRO 126	0	0	0	37.9	180.4		ELECT*	(.1)	(79.9)	(172.0)	—	—	(252.0)	0	32	68	—	—	100%	0	25	14	—	—	—				
MIDDLE ATLANTIC	31,000,600	61,312	1,657,691	0	0	18	2	FOSSIL 225	87,079	4,374	87,627	29,746	19,943	2,992.5	COAL	—	971.2	9.7	1,038.0	105.2	2,124.1	—	46	0	49	5	100%	—	44	0	40	90	22	-193.0	5338.8	1564.5	6709.4
								NUCLEAR 8							OIL	2,352.1	378.9	1,660.2	960.9	12.1	5,364.2	44	7	31	18	0	100%	99	17	51	37	10	55				
	818,937.0	355.6	1,818.5	0	0			HYDRO 224	2,318.0	25.4	96.2	340.3	212.6		NG	25.1	505.0	1,067.7	62.9	—	1,660.7	2	30	64	4	—	100%	1	23	33	2	—	17				
SOUTH ATLANTIC	44,319,900	334,919	2,619,154	0	0	9	5	FOSSIL 273	139,124	39,019	747,672	17,369	24,931	4,652.9	ELECT*	(0.8)	(365.5)	(685.1)	—	—	(1,051.4)	0	35	65	—	—	100%	0	18	34	—	—	—	-1364.1	4,655.0	1,242.0	4,532.9
								NUCLEAR 4							HYDRO	—	—	—	178.8	—	178.8	—	—	100	—	100%	—	—	—	5	—	2					
	1,184,595.4	1,942.5	2,873.1	0	0			HYDRO 129	3,710.3	226.3	271.6	178.8	265.9		NUCLEAR	—	—	—	265.9	—	265.9	—	—	100	—	100%	—	—	—	8	—	3	-58%	95%	82%	49%	
EAST NORTH CENTRAL	97,462,800	390,310	3,220,019	0	0	31	8	FOSSIL 428	127,352	59,581	162,000	3,318	28,264	3,854.7	COAL	—	1452.2	71.6	2830.6	8.7	4363.1	—	33	2	65	0	100%	—	35	2	80	17	32	1369.4	4473.4	4032.4	9875.2
								NUCLEAR 8							OIL	2,989.6	420.1	1,153.0	214.7	41.5	4818.9	62	9	24	4	1	100%	98	10	28	6	83	35				
	2,263,695.2	2,263.8	3,543.4	0	0			HYDRO 162	2,993.7	345.5	178.6	35.6	301.3		NG	59.2	1,675.8	2,304.8	171.2	—	4211.0	1	40	55	4	—	100%	2	41	55	5	—	31				
EAST SOUTH CENTRAL	29,509,100	366,698	2,430,792	0	0	14	12	FOSSIL 79	164,561	72,708	178,545	25,509	6,289	5,114.3	ELECT*	(1.4)	(590.5)	(647.2)	—	—	(1239.1)	0	48	52	—	—	100%	0	14	15	—	—	—				
								NUCLEAR 1							HYDRO	—	—	—	35.6	—	35.6	—	—	100	—	100%	—	—	—	1	—	0					
	736,316.4	2,126.9	2,666.5	0	0			HYDRO 53	4,200.8	421.8	195.9	228.8	67.0		NUCLEAR	—	—	—	301.3	—	301.3	—	—	100	—	100%	—	—	—	8	—	2	-160%	73%	82%	-12%	
WEST NORTH CENTRAL	30,191,300	594,680	12,192,022	0	0	19	36	FOSSIL 709	13,393	88,549	920,559	12,993	9,290	2,031.7	COAL	—	123.4	13.1	737.8	0.3	874.6	—	14	2	84	0	100%	—	12	1	52	1	16	638.2	1,662.9	1,046.8	3,347.9
								NUCLEAR 5							OIL	1,466.0	123.7	524.4	38.8	23.5	2,176.4	67	6	24	2	1	100%	93	12	31	3	99	41				
	529,297.3	3,449.1	13,374.6	0	0			HYDRO 62	236.4	513.5	1,009.8	173.0	99.0		NG	188.3	672.2	903.6	362.5	—	2,056.6	6	33	44	18	—	100%	7	63	53	26	—	38				
WEST SOUTH CENTRAL	5,231,800	16,566,733	158,096,878	87,800	0	84	567	FOSSIL 296	10,495	2,193,762	17,687,346	9,484	361	32,404.9	ELECT*	(0)	(358.7)	(278.8)	—	—	(637.5)	0	56	44	—	—	100%	0	26	31	—	—	—				
								NUCLEAR 1							HYDRO	—	—	—	228.8	—	228.8	—	—	100	—	100%	—	—	—	14	—	5					
	94,676.3	96,087.0	173,432.3	18,877.0	0			HYDRO 42	172.5	12,723.9	19,403.0	101.7	3.8		NUCLEAR	—	—	—	67.0	—	67.0	—	—	100	—	100%	—	—	—	4	—	2	-160%	73%	82%	-12%	
MOUNTAIN	185,388,800	2,275,698	19,676,653	1,151,800	600,000,000	38	92	FOSSIL 168	63,404	350,986	1,821,684	32,243	0	5,798.6	COAL	—	121.1	12.1	571.5	0	704.7	—	17	2	81	0	100%	—	14	1	46	0	19	-687.1	-637.7	-747.3	-2,072.1
								NUCLEAR 9							OIL	935.4	143.5	221.7	76.8	20.5	1,397.9	67	10	16	5	2	100%	93	16	25	6	100	37				
	3,979,737.4	13,199.1	21,585.4	247,637.0	3,290,000			HYDRO 167	1,391.8	2,035.6	1,998.4	372.8	0		NG	72.3	515.6	445.7	217.4	—	1,251.1	6	41	36	17	—	100%	7	58	51	18	—	34				
PACIFIC	13,601,200	13,651,135	37,061,204	0	0	46	46	FOSSIL 141	4,613	393,606	494,289	165,031	6,750	4596.5	ELECT*	(.1)	(109.5)	(198.0)	—	—	(307.6)	0	36	64	—	—	100%	0	12	23	—	—	—				
								NUCLEAR 3							HYDRO	—	—	—	372.8	—	372.8	—	—	100	—	100%	—	—	—	30	—	10					
	304,039.0	79,176.5	40,656.2	0	0			HYDRO 285	91.7	2,282.9	542.2	1,607.7	72.0		NUCLEAR	—	—	—	0	—	0	—	—	100	—	100%	—	—	—	3	—	1	32%	36%	76%	40%	

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

TABLE 3. EAST NORTH CENTRAL REGION SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																			NET IMPORTS (FOREIGN & DOMESTIC)			
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM U ₃ O ₈ 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP
ILLINOIS	65,664,800	159,789	399,414	0	0	11	1	FOSSIL 98	58,214	27,553	1,436	106	19,592		COAL	—	169.6	17.6	628.1	1.9	817.2	—	21	2	77	0	100%	—	18	1	65	9	22	-508.9	1319.2	1186.1	1,996.4
								NUCLEAR 3							OIL	872.0	189.7	322.8	75.4	19.1	1,479.0	59	13	22	5	100%	98	21	27	8	91	40					
															NG	19.5	431.5	692.1	44.6	—	1,187.7	2	36	58	4	100%	2	47	57	5	—	32					
	1,495,844.1	926.8	438.2	0	0										ELECT*	(1.2)	(124.5)	(185.0)	—	—	(310.7)	0	40	60	—	100%	0	14	15	—	—	0					
INDIANA	10,622,600	24,351	64,141	0	0	70	0	FOSSIL 50	23,727	4,919	176	445	0		HYDRO	—	—	—	1.1	—	1.1	—	—	—	100	—	100%	—	—	—	0	—	0	421.9	737.7	544.0	1,703.5
								NUCLEAR 0							OIL	422.7	89.4	226.9	16.3	10.9	766.2	55	12	30	2	100%	97	10	40	3	92	34					
															NG	12.8	278.4	238.9	14.0	—	544.1	2	51	44	3	100%	3	32	43	2	—	24					
	246,444.3	141.2	70.4	0	0										ELECT*	(.1)	(90.5)	(85.8)	—	—	(176.4)	0	51	49	—	100%	0	10	15	—	—	0					
MICHIGAN	118,200	82,299	1,458,254	0	0	6	7	FOSSIL 104	0	18,021	69,133	1,051	416		HYDRO	—	—	—	4.5	—	4.5	—	—	—	100	—	100%	—	—	—	1	—	0	43%	96%	100%	74%
								NUCLEAR 2							OIL	647.8	44.9	235.8	83.1	5.2	1,016.8	64	4	23	8	100%	98	6	26	12	63	38					
															NG	11.2	345.0	546.5	57.4	—	950.1	1	36	57	6	100%	2	49	59	9	—	36					
	2907.7	477.3	1599.7	0	0										ELECT*	(0)	(111.8)	(128.0)	—	—	(239.8)	0	47	53	—	100%	0	16	14	—	—	0					
OHIO	21,077,200	123,871	1,308,210	0	0	6	0	FOSSIL 97	45,411	9,088	92,055	10	0		HYDRO	—	—	—	11.1	—	11.1	—	—	—	100	—	100%	—	—	—	2	—	0	472.6	999.8	1024.2	2,496.6
								NUCLEAR 0							OIL	738.4	78.8	196.9	34.6	3.8	1,052.5	70	8	19	3	100%	99	6	19	3	59	28					
															NG	10.2	452.6	641.5	20.9	—	1,125.2	1	40	57	2	100%	1	34	61	2	—	30					
	518,499.1	718.5	1435.1	0	0										ELECT*	(.1)	(219.4)	(178.6)	—	—	(398.1)	0	55	45	—	100%	0	16	17	—	—	0					
WISCONSIN	0	0	0	0	0	1	0	FOSSIL 79	0	0	0	1,706	8,256		HYDRO	—	—	—	.1	—	.1	—	—	—	100	—	100%	—	—	—	0	—	0	275.1	504.4	393.9	1,173.4
								NUCLEAR 3							OIL	308.7	17.3	170.6	5.3	2.5	504.4	61	3	34	1	100%	98	6	39	1	93	39					
															NG	5.5	168.3	185.8	34.3	—	393.9	1	43	47	9	100%	2	59	43	10	—	31					
	0	0	0	0	0										ELECT*	(0)	(44.3)	(69.8)	—	—	(114.1)	0	39	61	—	100%	0	15	16	—	—	1					
EAST NORTH CENTRAL	97,462,800	390,310	3,230,019	0	0	31	8	FOSSIL 428	127,352	59,581	162,600	3,318	28,264		HYDRO	—	—	—	18.8	—	18.8	—	—	—	100	—	100%	—	—	—	5	—	1	31%	93%	96%	72%
								NUCLEAR 8							OIL	2,989.6	420.1	1,153.0	214.7	41.5	4818.9	62	9	24	4	100%	98	10	28	6	83	35					
															NG	55.2	1,675.8	2,304.8	171.2	—	4211.0	1	40	55	4	100%	2	41	55	5	—	31					
	2,263,695.2	2,263.8	3,543.4	0	0										ELECT*	(1.4)	(590.5)	(647.2)	—	—	(1239.1)	0	48	52	—	100%	0	14	15	—	—	0					
															HYDRO	—	—	—	35.6	—	35.6	—	—	100	—	100%	—	—	—	1	—	0	31%	93%	96%	72%	
															NUCLEAR	—	—	—	301.3	—	301.3	—	—	100	—	100%	—	—	—	8	—	2					
															TOTAL	3,048.8	3,548.1	3,529.4	3,553.4	50.2	3,729.9	22	26	26	26	0	100%	100%	100%	100%	100%	100%					

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

SOURCE: AND U.S. BUREAU OF MINES (1)

TABLE 4. UNITED STATES SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION															NET IMPORTS (FOREIGN & DOMESTIC)							
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM 10 ³ LBS	OIL SHALE 10 ³ TONS	OIL RECOVERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁹ KWHR	NUCLEAR ELECTRIC 10 ⁹ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)							SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR					COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP						
REGIONAL TOTALS	436,725,500	34,241,485	236,964,413	1,239,600	600,000,000	261	768	FOSSIL 2,456	610,021	3,202,585	21,600,522	300,466	112,740		COAL 17,018.8	3689.2	158.6	8375.2	118.8	12341.8		57	30	1	68	1	100%		19	1	42	37	18	-2,608.4	11431.2	-1710.2	6947.6
								NUCLEAR 36							OIL 682.8	3190.7	6115.1	3400.8	200.8	30006.2		3	10	20	12	1	100%	96	16	44	18	63	44				
								HYDRO 1152	15,120.7	18,575.0	23,695.8	3076.5	1,201.8	61,669.7	NG (16.0)	2667.4	3723.2			(6406.6)		0	42	58		100%	0	13	27								
	9,911,294.0	198,600.6	259,950.0	266,514.0	3,290,000										ELECT*											100%											
															HYDRO											100%											
															NUCLEAR											100%											
															TOTAL	17701.6	17163.5	13769.6	19657.5	319.6	68611.9	26	25	20	29	0	100%	100%	100%	100%	100%	100%	100%				
UNDISTRIBUTED ITEMS	-100	8,471	168,084	40,400	0	0	0	FOSSIL 0	2	0	0	16,474	837		COAL	2.7	440.0	138.9	144.4	-118.8	606.6						100%										
								NUCLEAR 0							OIL	714.8	2718.7	-16.3	-6	44.5	3461.1						100%										
	-22.7	49.1	184.4	8,686.0	0			HYDRO 0	-633.8	0	-6.5	232.5	9.2	562.6	NG	2.0	-265.4	22.1	-11.8	-253						100%											
															ELECT*	0	(2.6)	(2.8)		(5.4)						100%											
															HYDRO		33.0		199.5		232.5					100%											
															NUCLEAR				9.2		9.2					100%											
															TOTAL	718.9	2926.3	144.7	340.7	-74.3	4056.3						100%	100%	100%	100%	100%	100%	100%	100%			
U.S. TOTAL	436,725,400	34,249,956	237,132,497	1,280,000	600,000,000	261	768	FOSSIL 2456	610,023	3,202,585	21,600,522	316,920	113,577		COAL	2.1	4129.2	297.5	8519.6	0	12948.4		32	2	66	0	100%		18	2	43	0	18	-1374.4	14892.3	-1956.8	11561.1
								NUCLEAR 36							OIL	17733.6	5909.4	6098.8	3480.2	245.3	33467.3	53	18	18	10	1	100%	96	26	34	17	100	46				
								HYDRO 1152	14,486.9	18,575.0	23,689.3	3,309.0	1,211.0	61,271.2	NG	684.8	10018.2	7518.0	3511.5	0	21732.5		3	46	35	16	100%	4	44	43	18		30				
	9,911,291.7	198,649.7	260,134.3	275,200.0	3,290,000										ELECT*	(16.0)	(2670.0)	(3726.0)		(6412.0)		0	42	58		100%	0	12	21								
															HYDRO		33.0		3276.0		3309.0					100%											
															NUCLEAR				1211.0		1211.0					100%											
															TOTAL	18420.5	20089.8	13914.3	19998.2	245.3	72668.2	25	28	19	28	0	100%	100%	100%	100%	100%	100%	100%				

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

SOURCE: AND U.S. BUREAU OF MINES (1)

Table 6. States by Census Region

NEW ENGLAND

Connecticut	New Hampshire
Maine	Rhode Island
Massachusetts	Vermont

MIDDLE ATLANTIC

New Jersey	Pennsylvania
New York	

SOUTH ATLANTIC

Delaware	North Carolina
Florida	South Carolina
Georgia	Virginia
Maryland & D.C.	West Virginia

EAST NORTH CENTRAL

Illinois	Ohio
Indiana	Wisconsin
Michigan	

EAST SOUTH CENTRAL

Alabama	Mississippi
Kentucky	Tennessee

Table 6. States by Census Region (continued)

WEST NORTH CENTRAL

Iowa	Nebraska
Kansas	North Dakota
Minnesota	South Dakota
Missouri	

WEST SOUTH CENTRAL

Arkansas	Oklahoma
Louisiana	Texas

MOUNTAIN

Arizona	Nevada
Colorado	New Mexico
Idaho	Utah
Montana	Wyoming

PACIFIC

Alaska	Oregon
California	Washington
Hawaii	

All reserves data are given in standard units (e.g., tons, barrels) and trillion (10^{12}) Btus. Conversion factors used to convert standard units of reserves to Btus are given in Table 7.

Processing (Number)

The processing section of the supply/demand profile gives the number of oil refineries, natural gas plants and electric power plants in each state and region. The electric power plants are categorized as fossil fuel, nuclear or hydropower plants. The number of oil refineries, coupled with actual production data, is an indicator of a state's or region's capability of converting crude oil into petroleum products. However, processing capacity should not be based on the number of plants alone. The age, efficiency and percent of the plant in use are also important factors to consider. Statistics on the capacity of oil refineries, natural gas plants and electric power plants must be coupled with the actual plant output to be meaningful.

Primary Resource Production

The first three columns of the production section show the amounts of coal, oil, and natural gas, that were extracted within each state or region in 1974. The amount of hydro and nuclear electric power produced is included in the next two columns. The total production for all types is given as a summation of the heat values of the energy produced from all sources. Conversion factors which were used to convert standard units of production to Btus are given in Table 7.

Consumption

To facilitate assessment of consumption patterns, each region is divided into five economic sectors: transportation, industrial, residential/commercial, electric utility and miscellaneous. The energy resources considered for each sector are: coal, oil, natural gas, electricity, hydropower and nuclear. Energy consumption is given in trillion (10^{12}) Btus. Consumption of nuclear and hydropower by electric utilities is considered to be the thermal equivalent of fossil-fueled electric power plants. The distributed electricity is treated as a non-add item in determining total gross energy consumption.

TABLE 7
CONVERSION FACTORS

Anthracite - 25,400,000 Btu/short ton

Bituminous coal and lignite - The heat value of bituminous coal and lignite is the median value of analyses by the Bureau of Mines of coal samples delivered to government installations from a producing state and samples obtained at mines and preparation plants during the years 1960-1972. The following tabulation shows individual values used in each state:

<u>State</u>	<u>Btu/short ton</u>
Alabama	25,740,000
Alaska	22,860,000
Arizona	21,840,000
Arkansas	25,460,000
Colorado	22,320,000
Illinois	22,780,000
Indiana	23,200,000
Iowa	19,420,000
Kansas	24,340,000
Kentucky	25,460,000
Maryland.....	25,440,000
Missouri.....	21,800,000
Montana	21,580,000
New Mexico	23,080,000
North Dakota	14,280,000
Ohio	24,600,000
Oklahoma	25,240,000
Pennsylvania	26,720,000
Tennessee	26,200,000
Texas	13,200,000
Utah	25,440,000
Virginia	26,360,000
Washington	19,340,000
West Virginia	26,800,000
Wyoming	20,620,000

Crude Oil - 5,800,000 Btu/bbl

Hydroelectric - 10,465Btu/kWhr (average)

Natural Gas (wet) - 1,095 Btu/cu ft
(dry) - 1,024 Btu/cu ft

Nuclear - 215,000,000 Btu/pound of U_3O_8

Oil Shale - 5,800,000 Btu/bbl

Sources: References (1) (4) (10)

The percentage of each fuel type consumed by each economic sector has been calculated to show the relative importance of the various sectors in consumption of specific fuel types. The extent to which each economic sector is dependent on each fuel type is also given. The dependency figures include electricity distributed for each sector. Total primary resource consumption figures, however, do not include electricity distributed since electricity is not a primary resource. This is indicated by the use of parentheses around such figures.

Net Imports (Foreign and Domestic)

The quantity of net imports is determined by subtracting total production from total consumption for each fuel type in each state and region. Exports are shown as negative values. The figures below the Btu values list the percentage of a fuel that is imported/exported by a state or region in terms of the fuel consumed in the region. Again, negative values indicate net exports.

B. ENERGY INDICES

A set of Energy Indices has been developed to aid in the analysis of regional and consumption sector data discussed in Section A. For maximum utility, these indices must reflect the amount, mix and scarcity of fuels consumed by the various regions and sectors. This has been accomplished by making the indices functions of the depletion rates of the various fuels, i.e., production. The higher the depletion rate, the scarcer is the particular fuel reserves.

Weighting of Various Fuels in Indices

In order for the indices to reflect the scarcity of certain fuels in energy demand, each fuel type is weighted. This weighting takes into account the relative abundance of coal in comparison with petroleum and natural gas, i.e., index values are weighted heavier for oil and gas than coal. The scarcity of the fuel is related to the rate at which that fuel reserve is being depleted.

Weighting factors chosen for use in this program are linear functions of the various fuel depletion rates. They were calculated using the U.S. depletion rate for each fuel as follows:

$$\text{WEIGHTING FACTOR} = \frac{\text{Production}}{\text{Reserves}}$$

Production and reserves data were obtained from the 1974 U.S. supply/demand profiles, Table 5.^{3/} They reflect the proven reserves as determined by the U.S. Department of Energy.^{3/} The rate of depletion results were then normalized so that the sum of the resulting weighting factors would equal 100:

$$\text{WEIGHTING FACTOR/(Coal)} = W_C = \frac{610,023 \times 10^3}{436,725,400 \times 10^3} \frac{\text{tons}}{\text{tons}} = .00140 \quad 0.7$$

$$\text{WEIGHTING FACTOR/(Oil)} = W_0 = \frac{3,202,585 \times 10^3 \text{ bbl}}{34,249,956 \times 10^3 \text{ bbl}} = .09351 \quad 45.8$$

$$\text{WEIGHTING FACTOR/(Gas)} = W_G = \frac{21,600,552 \times 10^6}{237,132,497 \times 10^6} \frac{\text{cu ft}}{\text{cu ft}} = .09109 \quad 44.7$$

$$\text{WEIGHTING FACTOR/(Nuclear)} = W_N = \frac{23,056 \times 10^3}{1,280,000 \times 10^3} \frac{\text{lbs}}{\text{lbs}} = .01801 \quad 8.8$$

Hydroelectric energy is assigned a weighting factor of zero because it is a renewable resource and does not have a definable depletion rate. Other renewable resources, such as geothermal and solar energy, also would have weighting factors of zero. Shale has a weighting factor of zero because it is not in production.

The Energy Indices

The four energy indices are:

- U = Consumption or Utilization Index
D = Dependence Index
P = Population-Induced Consumption Index
I = Industry-Induced Consumption Index

Each index is defined to reflect a specific energy characteristic of a region.

3/ The reserves of coal reported by the Energy Information Administration are the demonstrated reserve base. The amount of coal that can be recovered a deposit ranges from 50 to 90 percent of the demonstrated reserve base, depending upon the location and geologic formation of the coalbed as well as the method of recovery.

1. Consumption Index

The Consumption or Utilization Index represents the fuel weighted share of total national energy use by each region or regional sector. Values are calculated as follows:

$$U = n \sum_i W_i \left(\frac{C_R^i}{C_T} \right)$$

where: U = Consumption Index

n = a normalization constant

i = type of fuel: coal, oil, gas and nuclear

W_i = weighting factor for each fuel

C_R^i = consumption of each fuel in the region

C_T = total national consumption of all fuels.

Total U. S. energy consumption is considered first. The overall U. S. consumption index is given by:

$$U_{U.S.} = N \sum_i W_i \left(\frac{C_T^i}{C_T} \right)$$

where: N = a normalization constant

i = type of fuel: coal, gas, oil and nuclear

W_i = weighting factor for each fuel

C_T^i = total U. S. consumption of each fuel

C_T = total U. S. consumption of all fuels.

Entering consumption data from Table 4 for coal, oil, natural gas and nuclear,⁴ in the above expression yields:

⁴Consumption data are in units of 10^{12} Btus from the regional Totals row of Table 4. To facilitate later comparisons among regions, these figures do not include the "undistributed items", which are primarily industrial oil and coal consumption which cannot be assigned to a region.

$$\begin{aligned}
U_{U.S.} &= N \left[.7 \left(\frac{12,341.8}{68,611.9} \right) + 45.8 \left(\frac{30,005.2}{68,611.9} \right) \right. \\
&\quad \left. + 44.7 \left(\frac{21,985.6}{68,611.9} \right) + 8.8 \left(\frac{1,201.8}{68,611.9} \right) \right] \\
&= N[34.63]
\end{aligned}$$

Since the overall U. S. consumption index is to be normalized to 100,

$$U_{U.S.} = 100 = N[34.63]$$

Hence, the value of the normalization constant is given by:

$$N = \frac{100}{34.63} = 2.888$$

The East North Central region is used as an illustration of the calculation of a regional Consumption Index. Using data from Table 3, the regional Consumption Index is given by:

$$\begin{aligned}
U_R &= n \sum_i w_i \left(\frac{C_R^i}{C_T} \right) \\
&= n \left[.7 \left(\frac{4,363.1}{68,611.9} \right) + 45.8 \left(\frac{4,818.9}{68,611.9} \right) \right. \\
&\quad \left. + 44.7 \left(\frac{4,211.0}{68,611.9} \right) + 8.8 \left(\frac{301.3}{68,611.9} \right) \right] \\
&= n[6.04]
\end{aligned}$$

The appropriate normalization constant, n , in the above expression is, however, different from that previously given in the overall U.S. Consumption Index. If the same normalization constant were used, Consumption Index values for the various regions would sum to the overall U.S. Index, 100. It is more desirable to scale these indices to an average value of 100, so that it can be seen at a glance whether a particular value is above or below the national average. This is readily accomplished by multiplying the U.S. normalization constant by the number of regions, 9,

$$n = 9N = 9(2.888)$$

Hence, for the East North Central region,

$$U_R = 9(2.888)6.04 = 157$$

Consumption Indices have been calculated for each consuming sector in each of the 9 regions. The Industrial sector of the East North Central region is chosen to exemplify these calculations:

$$U_R^I = n \sum_i W_i \left(\frac{C_R^{iI}}{C_T} \right)$$

Where: U_R^I = Consumption Index for Industrial Sector

n = a normalization constant

i = type of fuel: coal, oil, gas and nuclear

W_i = weighting factors for each fuel

C_R^{iI} = consumption of each fuel in the industrial sector of the region

C_T = total U.S. consumption of all fuels.

$$= n \left[.7 \left(\frac{1,452.2}{68,611.9} \right) + 45.8 \left(\frac{420.1}{68,611.9} \right) + 44.7 \left(\frac{1,675.8}{68,611.9} \right) \right]$$

$$= n[1.39]$$

In order to scale such values to an average value of 100, the appropriate normalization constant is given by:

$$n = \frac{(\text{U.S. normalization constant}) (\text{number of consuming sectors})^5}{(\text{number of regions})}$$

$$n = (2.888) (4) (9) = 104.0$$

Hence,

$$U_R^I = 104.0 [1.39] = 144$$

⁵Consuming sector comparisons in this report are limited to the following sectors: transportation, industrial, residential/commercial and electric utility. The relatively minor energy consumption in the "miscellaneous" sector is not considered further. Hence, the appropriate number of consuming sectors is 4.

2. Dependence Index

The Dependence Index reflects how heavily a region or regional sector relies on the scarcer fuels. Values are calculated as follows:

$$D = n \sum_i W_i \left(\frac{C_R^i}{C_R} \right)$$

D = Dependence Index

n = a normalization constant

i = type of fuel: coal, oil, gas and nuclear

W_i = weighting factor for each fuel

C_R^i = consumption of each fuel in the region

C_R = total regional consumption of all fuels

The overall U.S. Dependence Index is normalized to 100. Since the "region" being considered is the entire U.S., the expression for the U.S. Dependence Index is identical to that for the U.S. Consumption Index, and the normalization constants are also the same.

An example of the calculation of a regional Dependence Index for the East North Central region is as follows (data from Table 3):

$$\begin{aligned} D_R &= n \sum_i W_i \left(\frac{C_R^i}{C_R} \right) \\ D_R &= n \left[.7 \left(\frac{4,363.1}{13,729.9} \right) + 45.8 \left(\frac{4,818.9}{13,729.9} \right) \right. \\ &\quad \left. + 44.7 \left(\frac{4,211.0}{13,729.9} \right) + 8.8 \left(\frac{301.3}{13,729.9} \right) \right] \\ &= n[30.20] \end{aligned}$$

Note that the Dependence Index, D , is unique in that it is independent of the amount of fuels consumed within a region and is based solely on the mix of fuels consumed. This results from the use of C_R , total regional fuel

consumption, rather than C_T , total national fuel consumption, in the denominator of the defining equation. To very close approximation⁶ the appropriate normalization constant to use is identical to that calculated above for the U.S. Dependence Index, i.e., $n=2.888$. Hence,

$$D_R = 2.888[30.20] = 87$$

⁶The Dependence Index, D_R , for a given region is given by:

$$D_R = n \left[\sum_i W_i \frac{C_R^i}{C_R} \right]$$

The average value of the regional Dependence Index can be calculated by summing all the regional Dependence Indices and dividing by the number of regions, 9,:

$$D_R = \frac{n}{9} \left[\sum_{R=1}^9 \sum_i W_i \frac{C_R^i}{C_R} \right]$$

The normalization constant, n , is chosen to make the average value of the Regional Dependence Index 100:

$$D_R = \frac{n}{9} \left[\sum_{R=1}^9 \sum_i W_i \frac{C_R^i}{C_R} \right] = 100$$

The overall U.S. Dependence Index, which is also normalized to 100, can be expressed as:

$$D_{U.S.} = N \left[\sum_i \frac{W_i C_T^i}{C_T} \right] = 100$$

Since total U.S. consumption of each fuel and total U.S. consumption of all fuels can be obtained by summing regional totals:

$$D_{U.S.} = N \left[\frac{\left(\sum_{R=1}^9 \sum_i W_i C_R^i \right)}{\left(\sum_{R=1}^9 C_R \right)} \right]$$

(Footnote continued on next page.)

⁶(Continued)

The denominator of the above equation can be expressed as follows:

$$\sum_{R=1}^9 C_R = C_T = 9C_R$$

where: C_R = average regional consumption of all fuels.

Hence,

$$D_{U.S.} = \frac{N}{9} \left[\sum_{R=1}^9 \sum_i \frac{W_i C_R^i}{C_R} \right] = 100$$

The assumption that $n = N$ is therefore equivalent to assuming that

$$\sum_{R=1}^9 \sum_i \frac{W_i C_R^i}{C_R} = \frac{1}{C_R} \left[\sum_{R=1}^9 \sum_i W_i C_R^i \right]$$

Analysis of the data indicates that this assumption is accurate to within less than 1 percent error.

The Dependence Index for the industrial sector of the East North Central region is given by:

$$D_R^I = n \sum_i W_i \left(\frac{C_F^{iI}}{C_F^I} \right)$$

where: D_R^I = Dependence Index for Industrial Sector of the region

n = a normalization constant

i = type of fuel: coal, oil, gas and nuclear

W_i = weighting factor for each fuel

C_R^{iI} = consumption of each fuel in the industrial sector of the region

C_R^I = total regional consumption of all fuels in the industrial sector

$$\begin{aligned} D_R^I &= n \left[.7 \left(\frac{1,452.2}{3,548.1} \right) + 45.8 \left(\frac{420.1}{3,548.1} \right) + 44.7 \left(\frac{1,675.8}{3,548.1} \right) \right] \\ &= n[26.72] \end{aligned}$$

(Footnote continued on next page.)

⁶(Continued)

The same normalization constant is used for all Dependence Index calculations in this report, $n = 2.888$. Hence,

$$D^I = 2.888 [26.72] = 77$$

3. Population-Induced Consumption Index

The residential/commercial sector and that portion of the energy delivered to the residential/commercial sector by the electric utility sector are included in the index formulation. In addition to these sectors, oil used for transportation is included. The index values are calculated as follows:

$$F = n \left[w_C \left(\frac{C_R^{C,R/C}}{C_T} + (F^{R/C}) \frac{C_R^{C,E}}{C_T} \right) + w_O \left(\frac{C_R^{O,T}}{C_T} + \left(\frac{C_R^{C,R/C}}{C_T} \right) + (F^{R/C}) \left(\frac{C_R^{C,E}}{C_T} \right) \right) + w_G \left(\frac{C_R^{G,R/C}}{C_T} + F^{R/C} \frac{C_R^{G,E}}{C_T} \right) + w_N (F^{R/C}) \left(\frac{C_R^{N,E}}{C_T} \right) \right]$$

where: F = Population-Induced Consumption Index

n = a normalization constant

w_i = weighting factor for each fuel: coal, oil, gas and nuclear

$C_R^{A,B}$ = regional consumption for each specific fuel and population-related sector (e.g., $C_R^{G,R/C}$ = regional consumption of coal in residential/commercial sector), $C_R^{C,E}$ = regional consumption of coal in electric utility sector; $C_R^{O,T}$ = regional consumption of oil in transportation sector; $C_R^{O,R/C}$ = regional consumption of oil in residential/commercial sector, etc.

C_T = total national consumption of all fuels

$F^{R/C}$ = proportion of electricity distributed that goes to the R/C sector

Calculation of the appropriate normalization constant proceeds in a manner similar to that described above. First, an overall U.S. expression for P is set up and assigned a value of 100. This determines the respective U.S. normalization constant. In order to scale average regional values to 100,

$$n = 9N$$

where: n = regional normalization constant

N = U.S. normalization constant

9 = number of U.S. census regions

4. Industry-Induced Consumption Index

This index represents energy consumption in the industrial sector, including delivered electricity. The index values are calculated as follows:

$$I = n \left[W_C \left(\frac{C_R^{C,I}}{C_T} = (F^I) \frac{C_R^{C,E}}{C_T} \right) + W_O \left(\frac{C_R^{O,I}}{C_T} + (F^I) \frac{C_R^{O,E}}{C_T} \right) + W_G \left(\frac{C_R^{G,I}}{C_T} + (F^I) \frac{C_R^{G,E}}{C_T} \right) + W_N (F^I) \left(\frac{C_R^{N,E}}{C_T} \right) \right]$$

where: I = Industry-Induced Consumption Index

n = a normalization constant

W_i = weighting factor for each fuel: coal, oil, gas and nuclear

$C_R^{A,B}$ = regional consumption for each specific fuel and industry-related sector (e.g., $C_R^{C,I}$ = regional consumption of coal in the industrial sector)
 C_T = total national consumption of all fuels
 F^I = proportion of electricity distributed that goes to the industrial sector

Calculation of the normalization constant, n , proceeds as described above.

5. Properties of Index Values

The indices are scaled so that the larger the index value, the more the region consumes scarce fuels relative to other regions and to the U.S. as a whole. Index values are normalized so that the average index value for the U.S. is 100. The regional values for the indices may be greater or less than the U.S. figure of 100. For example, a region with a Consumption Index, U , value of 120 consumes more scarce energy resource than another region with a U value of 95. Also, the former region has a higher Consumption Index than the national average and the latter region a lower Consumption Index than the national average.

It should be emphasized that the index values are relative. Absolute magnitudes, per se, are not significant, but are meaningful only in relation to other regions and to the cumulative or average national energy situation.

The indices are particularly useful for rapid and efficient screening of national energy data. They indicate those regions and consumption sectors where further detailed analysis could be effective in improving the overall national energy posture. For example, a Dependence Index, D , of

less than 100 for a region indicates more acceptable energy-efficient usage patterns than the national average. Acceptable usage patterns can be studied to determine if they could be emulated in other regions. Similarly, a very large value for a regional Consumption Index, U, indicates that there is much room for improvement. Also, improvement in such regions will have a correspondingly large effect on the overall U.S. energy situation.

As noted above, the index values are sensitive to the mix of fuels consumed. This is accomplished by giving far more weight to petroleum and natural gas (the fuels with most rapid depletion rates) than to the relatively more abundant nuclear and coal fuels. For example, assume that there are two regions with identical total energy consumption. One region consumes 25 percent coal and 75 percent oil and gas while another region consumes only 10 percent coal and 90 percent oil and gas. Although both regions consume the same amount of total energy, the region that consumes more oil and gas will have higher Consumption and Dependence Index values because of the fuel weighting effect.

The Consumption Index value, U, is also sensitive to the amount of fuel consumed. If two regions have identical fuel consumption mixtures, i.e., the percent of coal, oil, gas and nuclear of the total fuel consumed in the regions are the same, but one region consumes twice the amount of total fuel as the other, it will have a Consumption Index value double that of the other region. The Population-Induced Consumption Index, P, and the Industry-Induced Consumption Index, I, are similarly dependent on the amount of fuel consumed in a region.

The Dependence Index, D, is unique in being independent of the total amount of fuel consumed in a region. It is dependent solely on the particular fuel mix consumed. Hence, comparisons between Dependence Index values can be instructive in determining relative dependence on scarce fuel supplies, irrespective of regional size or population.

C. COMPARISON OF INDEX VALUES

The analytical usefulness of the calculated index values can now be demonstrated. Consider the index values in Table 8, the Energy Index Matrix. The West South Central region has the highest Consumption Index value (198) and the highest Dependence Index value (128). However, as

shown in Table 5, the East North Central region uses the most energy of all the census regions, including the West South Central. This can be explained by reviewing the fuel mix of each region. The West South Central region is almost exclusively a consumer of natural gas and oil, while the East North Central region consumes approximately one-third coal, one-third oil, and one-third natural gas. The total oil and gas consumed in the East North Central region is less than the total oil and gas consumed in the West South Central region. Therefore, although total energy consumption is less in the West South Central region, the high consumption of less abundant oil and gas results in the high Consumption Index value for that region. The high dependence of the West South Central region on oil and gas (98 percent) accounts for its high Dependence Index value.

Another interesting comparison of index values is the East North Central region's high Consumption Index value (157) and low Dependence Index value (87), in contrast to the New England region's low Consumption Index value (45) and high Dependence Index value (121). The East North Central region consumes more oil and gas than five other regions' total consumption of all fuels, and this results in a high value in the Consumption Index. In contrast, the New England region is one of the lowest consumers of energy. As mentioned previously, the East North Central region uses more than 4 quads of coal, in addition to its consumption of large quantities of oil and gas. The East North Central region Dependence Index value, therefore, is low because it is proportionately less dependent on oil and gas (66 percent) than the New England region (91 percent).

Alternative scenarios can be evaluated using these index values as a base. For example, if it were proposed to convert 25 percent of the electric power plants from oil to coal, a recalculation of the index values and a comparison with the base values would show the resulting regional and nationwide impact. Index values would be reduced by the substitution of more abundant coal for scarcer petroleum fuel. The reductions would occur because of the differential effects of the weights for each fuel type. Calculations of this type and other scenario evaluations are presented and discussed in Chapter IV.

Table 8 Energy Index Matrix

REGION	CONSUMPTION INDEX	DEPENDENCE INDEX	POPULATION- INDUCED CONSUMPTION INDEX	INDUSTRY- INDUCED CONSUMPTION INDEX
NEW ENGLAND	45	121	57	22
MIDDLE ATLANTIC	122	96	147	74
SOUTH ATLANTIC	112	93	124	87
EAST NORTH CENTRAL	157	87	167	128
EAST SOUTH CENTRAL	46	77	46	41
WEST NORTH CENTRAL	73	104	81	52
WEST SOUTH CENTRAL	198	128	118	368
MOUNTAIN	46	93	46	42
PACIFIC	101	100	109	87
U.S.	100	100	100	100

SOURCE: SCI Calculations from 1974 Supply/Demand Profiles.

1. REGIONAL AND CONSUMING SECTOR INDICES

The Energy Index Matrix and index values, described above, can be used to identify those regions which are most at risk because of their consumption of scarce energy fuels. To be more precise, it is necessary to examine more closely the regional consuming sectors and fuels used by each sector. A more detailed analysis can be based upon a Regional Energy Matrix. An example is presented in Table 9. The Regional Matrix amplifies and provides further detail of index values in the Energy Index Matrix. The following is a line-by-line description of what is included in the matrix and an analysis of the East North Central region as an illustration.

a. Consumption Index

For each index, the index value from Table 8 is listed in a block on the left hand side of Table 9. The weighted and normalized fuel component values are listed in the same row on the right hand side under C (Coal), O (Oil), G (Natural Gas), N (Nuclear), and H (Hydro). The fuel component values sum to the index value in the box. Sector weighted index values are listed for the four major consuming sectors. Across from the sector index values are quads consumed by sector and fuel type.

TABLE 9
REGIONAL ENERGY MATRIX

EAST NORTH CENTRAL

INDEX	INDEX VALUE	SECTOR	COMPONENT INDEX AND CONSUMPTION (absolute and percentage)				
			C	O	G	N	H
C CONSUMPTION	157		1	84	71	1	0
			CONSUMPTION (10 ¹⁵ BTU)				
		TRANS 211	0	3.0	0.1	-	-
		INDUS 144	1.5	0.4	1.7	-	-
		R/C 236	0	1.2	2.3	-	-
		ELEC 34	2.8	0.2	0.2	0.3	0
D DEPENDENCE	87		1	46	40	0	0
			DEPENDENCE (PERCENT)				
		TOTAL	32	35	31	2	0
		TRANS 132	0	93	2	-	-
		INDUS 77	41	12	47	-	-
		R/C 128	2	33	65	-	-
		ELEC 18	80	5	5	8	1
P POPULATION INDUCED CONSUMPTION	167		1	107	58	1	0
			DISTRIBUTION (PERCENT)				
			18	51	29	2	0
I INDUSTRY INDUCED CONSUMPTION	128		2	29	95	2	0
			DISTRIBUTION (PERCENT)				
			53	10	34	3	0

The Consumption Index value (157) in Table 9 is composed of the five weighted fuel components, but the greatest influence comes from the oil (84) and gas (71) components. These components are weighted to show which fuel components affect the total index value and by how much. The sector values indicate that the R/C sector (236) is the sector with greatest significance if advanced fossil energy technologies can be applied to reduce sector consumption of scarce fuels. The R/C sector uses 1.2 quads of oil, 2.3 quads of gas and effectively no coal. If advanced fossil energy technologies could be applied to reduce this high consumption of oil and gas, the resulting impact on the national consumption of these critical fuels could be substantial. For example, the gas presently consumed in the R/C sector of the East North Central region represents over 10 percent of the total U.S. gas consumption. In contrast to the R/C sector, the East North Central Electric Utility sector has a very low index value (34). As can be seen from Table 9, the reasons for this low sector value are the heavy use of abundant coal (2.8 quads), use of nuclear fuel (.3 quad) and low consumption (0.2 quad each) of oil and gas.

b. Dependence Index

The Dependence Index value is listed in the block. The weighted fuel component values are listed in the same row on the right hand side. The fuel component values sum to the summary value. Sector weighted index values are listed for the four major consuming sectors. Across from the sector value is the percentage dependence of each sector on fuel type.^{7/}

The East North Central Region Energy Matrix in Table 9 shows that the region is quite evenly dependent on coal (32 percent), oil (35 percent) and natural gas (31 percent). The regional Dependence Index value (87) is low because of this usage of coal. The weighted fuel component values show that oil (46) and gas (40) are most influential, while coal (1) is only a small factor in the regional value because of the extremely low weighting

^{7/} The sector percentage dependence values in Table 9 (Regional Energy Matrix) are different from the sector percentage dependence values in Table 3 (ENC Supply/Demand Profile), because the former dependence percentages include electricity distributed, whereas the latter do not.

factor applied to this abundant resource. Both the transportation (132) and R/C (128) sectors have high sector values because of the high dependence on oil and natural gas. Even though the industrial sector is a high consumer of energy, (3.2 quads), it has a low sector dependence value (77) because it is 41 percent dependent on relatively abundant coal.

c. Population-induced Consumption Index

The Population-Induced Consumption Index value, (167), is listed in the block. The weighted fuel component values are listed across from the Index value. The fuel component values sum to the Index value. Below this line is the unweighted percentage distribution of fuel for the sectors included in the index. This percentage distribution adds to 100 percent.

The Population-Induced Consumption Index value for the East North Central region in Table 9 is very high (167) and reflects high energy consumption in the R/C and electric utility sectors, as well as consumption of oil in the transportation sector. The predominant weighted fuel component in the index value is oil (107), with consumption of natural gas a smaller but still significant component (58). It should also be noted, however, that 18 percent of the Population-Induced energy consumption is supplied by coal, primarily by widespread use of coal in the electric utility sector. Index values would be even larger without this widespread use of coal.

d. Industry-Induced Consumption Index

The data are arranged identically to the Population-Induced Consumption Index explained above.

The East North Central region's Industry-Induced Consumption Index value (128) is above the national average, but not so high as might be expected considering the large energy consumption in the industrial and the adjusted electric utility sectors. The reason is the 53 percent dependence on coal which on a weighted basis results in a fuel component value of 2. Natural gas is the fuel that could be a target for replacement by advanced fossil energy technologies because it has a weighted value of 95.

Values for Consumption and Dependence Indices for the four consuming sectors in each of the nine census regions are presented in Table 10. The values listed have been normalized, as discussed above, so that the average value of the 36 (nine regions x four consuming sectors) figures is 100. Note that this normalization does not mean that the average regional value of each individual consuming sector, e.g., industrial, is 100. The sectors with the highest Consumption Index values are those that are using the greatest quantities of oil and natural gas. Maximum national impact could be achieved by applying advanced fossil energy technologies to these sectors, technical and regional constraints permitting. This is discussed in detail in Section D, below.

A final comment is in order before discussing the potential impact of advanced fossil energy technologies on U.S. and regional energy requirements. The Energy Indices data base discussed above can be used for many additional calculations and comparisons. The key factor to be considered in the calculations is use of the appropriate normalization factor, so that the resultant values will scale to an average of 100. This leads to easy determination of which values are above or below national averages (less than 100 is below national average; greater than 100 is above national average). For example, if it is desired to focus exclusively on transportation sector energy consumption, the following procedure is recommended. The expression for the overall U.S. Transportation Consumption Index is set equal to 100, and the value of the U.S. normalization constant, N , determined. Regional Transportation Consumption Indices are then calculated with a normalization constant, $n = 9N$.

D. FOSSIL ENERGY TECHNOLOGIES AND REQUISITE REGIONAL RESOURCES

Seven advanced fossil energy technologies under development at DOE were selected for analysis: High Btu Gasification, Low Btu Gasification, Direct Combustion, Advanced Power Systems, Coal Liquefaction, Secondary and Tertiary Gas and Oil Extraction, and Oil Shale. Since each program-level technology includes many different processes with different output and

Table 10
Summary of Sector Consumption and
Dependence Index Values

	CONSUMPTION INDEX				
	<u>TOTAL</u>	<u>TRANS</u>	<u>INDUS</u>	<u>F/C</u>	<u>ELEC</u>
NE	45	54	16	74	35
MA	122	165	62	188	75
SA	112	191	78	87	90
ENC	157	211	144	236	34
ESC	46	87	45	42	11
WNC	73	110	54	98	29
WSC	198	169	394	76	152
M	46	70	45	46	21
P	101	170	85	87	59

	DEPENDENCE INDEX				
	<u>TOTAL</u>	<u>TRANS</u> ⁷	<u>INDUS</u>	<u>F/C</u>	<u>ELEC</u>
NE	121	132	129	132	91
MA	96	132	63	131	55
SA	93	132	90	127	50
ENC	87	132	77	128	18
ESC	77	132	83	127	12
WNC	104	132	112	129	40
WSC	128	132	129	130	120
M	93	132	110	128	32
P	100	132	123	130	44

⁷The transportation sector in all regions is 90 percent or more dependent on oil, and dependent on gas for the remainder. Since oil and gas weighting, 45.8 and 44.7, respectively, are not very dissimilar, the Dependence Index value for the transportation sector in each region is approximately the same, 132.

resource requirements, a typical process was selected which could serve as an example in each program area. The following processes were selected:

High Btu Gasification	Average Values of HYGAS, BIGAS, and Texaco
Low Btu Gasification	Average Values of Lurgi, and Westinghouse
Direct Combustion	30 MW Pope, Evans and Robbins Atmospheric Fluidized Bed Plant
Advanced Power Systems	635 MW Westinghouse Pressurized Fluidized Bed Combined Cycle Process
Coal Liquefaction	H-Coal Liquefaction Process
Gas and Oil Extraction	Domestic On-shore Crude Extraction
Oil Shale	Tosco II Retorting Process

Data collected on the seven technologies (6), (7), (8), (9), (10) and (11), included amount of product output; amount of required resources, such as coal, oil shale, electric power, water, and other materials; energy efficiency; air, water and solid waste by-products; and other relevant information. Time constraints did not permit a detailed collection of data from actual pilot plants and some of the data are from conceptual designs. However, it was the intent of this study to demonstrate only how the data could be used.

A typical Fossil Energy Technology Matrix for the East North Central region is presented in Table 11. Reading across the top from left to right, the matrix indicates:

1. The amount of primary and secondary products for each technology
2. Resource requirements for the application of each technology including fossil energy, electric power, water, other materials, land, labor and capital requirements
3. Energy efficiency for each technology and projected timing for full scale implementation

TABLE 11. EAST NORTH CENTRAL REGION
FOSSIL ENERGY TECHNOLOGY MATRIX

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS							APPLICATION INDEX
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL			REMARKS		
														AIR	WATER	SOLID WASTE			
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SHG 250 x 10 ⁶ CU FT/DAY 91,250 x 10 ⁶ BTU/FT-YEAR 1,000 BTU/CF 91.25 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY NAPHTHA - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(tons/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 45 tons/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF CAKING COALS WHICH AGGLOMERATE IN GASIFIERS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	●	
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CU FT/DAY 521,714 x 10 ⁶ CU FT/YEAR 175 BTU/CF 91.3 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6488 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5279 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLomite - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(tons/10 ¹² BTU INPUT) PARTICULATES 5 NOx 24 SOx 30-40 HC 3 CO 2	BOD 30ppm COD 25ppm TDS 250ppm	865 TONS/DAY (4,000 TONS/DAY OF SPENT DOLomite IF USED)	• UTILIZATION OF CAKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS OF SCALE-UP. • HIGH CAPITAL INVESTMENT.	●	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (39 MW) 720x10 ³ KWHR/DAY 263x10 ⁶ KWHR/DAY 3,412 BTU/KWHR 0.9 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES YR/10 ¹² BTU	UNKNOWN	\$ 20x10 ⁶ to \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 BTU/KWHR	1985 - 1990	(tons/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 ton/10 ¹² BTU TDS 18.2 tons/10 ¹² BTU	17 TONS/DAY	• FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • GASEOUS REGENERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.B. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	●	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWHR/DAY 5,563 x 10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 19.2x10 ¹² BTU/YR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	43.8x10 ⁶ KWHR/YR	6.1 MGD	DOLomite - 486 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE YR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(tons/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 tons/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGES LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.	●	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ BTU/BARREL 207.0 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,261x10 ⁶ KWHR/YR	3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT POLYBDEMUM 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 63%	1990 - 2000	(tons/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	BOD 10.5ppm COD 13.0ppm TSS 45.5ppm	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.	●	
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL .49 x 10 ³ BARRELS/DAY 178 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ BTU/BARREL 1 x 10 ¹² BTU/YEAR OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - YR/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 30% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(tons/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 tons/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. • RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAR SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	◐	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ⁶ BTU/BARREL 211.7 x 10 ¹² BTU/YEAR OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,489x10 ⁶ KWHR/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 67%	1985 - 1990	(tons/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	AMINES 1900ppm CARBONATES 520ppm CHLORIDES 330ppm CHROMATES 130ppm CYANIDES 50ppm ORGANICS ACIDS 1000ppm PHENOLS 60ppm	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A	

REGIONAL RESOURCES AND CHARACTERISTICS	REGIONAL CONSUMPTION (1974)	RESERVES - 97,482,800 x 10 ³ TONS		AVG BTU/TON - 23.2 x 10 ⁶ CAKING PROPERTIES - 25% CUMULATIVE PRODUCTION - 127,352 x 10 ³ TONS		RESERVES 390,310 x 10 ³ BARRELS		RESERVES 3,250,019 x 10 ⁶ Cu.Ft.		RESERVE (10 ³ TONS) -0-	DISTRIBUTED 363,182x10 ⁶ KWHR/YR	DEPLETION RATE CONSUMPTION (M.G.D.) 4,163	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE 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METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY
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4. Environmental considerations involving air and water pollutants and solid waste
5. A technology application symbol, discussed further below.

Similar matrices are presented for each of the nine census regions in Chapter III.

Regional resources and characteristics data are presented at the bottom of the matrix. Some of the data are from the regional Supply/Demand Profiles which include data on energy consumption, reserves and production. Sulfur content, surface or underground location, and the type of coal available come from references (12), (17), and (19). Limited coal, oil and gas transportation data are from references (13), (14), (15), (16), (18), and (19). Limited data on water availability for energy uses were obtained from reference (5). Air, water and solid waste standards were impossible to summarize on a regional basis. Future analyses, involving state level data, would make the environmental standards data much more useful.

All of the Fossil Energy Technologies under consideration presently have technical constraints which must be overcome before a technology can be successfully implemented. For example, Advanced Power Systems require the development of materials to successfully withstand high temperatures, Coal Liquefaction requires the development of improved solid-liquid separation techniques, etc. In this analysis it will be assumed that such technical constraints can be overcome and that the technologies can be implemented within the time frames noted in the Fossil Energy Technology Matrix.

1. Identification of Regional Constraints

The Fossil Energy Technology Matrix can be used to compare fossil energy technology resource requirements and characteristics with a region's resources and characteristics. The Matrix for each region provides quantitative data concerning the region and the seven technologies under consideration. The Fossil Energy Technology Matrix for the East North Central region, Table 11, is used as an example of how the technologies were compared with regional resources.

The applicability of a technology is primarily dependent on the region's reserves and production of the fuel used by the technology. The

first five technologies on the Matrix (High Btu Gasification, Low Btu Gasification, Direct Combustion, Advanced Power Systems, and Coal Liquefaction) require adequate reserves of coal. The East North Central region has large deposits of coal and is the third largest coal producing region. Most of the region's coal is high in sulfur content, which may account for the fact that coal production in the region does not cover the region's coal consumption. An efficient coal transportation system is provided by train, barge and truck linkages. Water is available in most parts of the ENC region. Hence, the first five technologies on the matrix are assessed as "applicable" to the region, as symbolized by the black bullet.

Of the last two technologies in the ENC Fossil Energy Technology Matrix, Oil Shale is assessed as "not applicable" for implementation within the region because there are no identified regional oil shale reserves with potential for producing 25 gallons per ton or more. This does not imply that products of oil shale technology produced in other regions could not have a substantial impact on the energy posture of the ENC region and transported to the ENC region via pipeline, etc.

Gas and Oil Extraction technologies could be applied in the ENC region but would not have much impact because reserves and production of gas and oil in the region are small. Therefore, the ENC region has a regional constraint (low supplies) that would limit the effectiveness of applying Gas and Oil Extraction techniques in the region. This regional constraint is indicated by the black and white bullet.

Similar regional requirements analysis for each of the nine census regions, detailed in Chapter III, leads to the quantitative result presented in Figure 3, Summary Fossil Energy Technology Matrix. In the following sector the potential impact of each of the technologies on regional energy postures will be more quantitatively addressed.

2. Quantification of Energy Impact

a. Index Analysis Approach

If a specific amount of each technology were assumed to be introduced into a specific region, the Energy Indices would change. Analysis could then be based on a comparison of the indices before and after the technologies had been introduced. Quantities and regional locations of

**FIGURE 3. SUMMARY
FOSSIL ENERGY TECHNOLOGY MATRIX**

REGION TECHNOLOGY	NEW ENGLAND	MID ATLANTIC	SOUTH ATLANTIC	EAST NORTH CENTRAL	EAST SOUTH CENTRAL	WEST NORTH CENTRAL	WEST SOUTH CENTRAL	MOUNTAIN	PACIFIC
HIGH BTU GASIFICATION	N/A	●	●	●	●	●	◐	●	◐
LOW BTU GASIFICATION	◐	●	●	●	●	●	◐	●	◐
DIRECT COMBUSTION	◐	●	●	●	●	●	◐	●	◐
ADVANCED POWER SYSTEMS	◐	●	●	●	●	●	◐	●	◐
COAL LIQUEFACTION	N/A	●	●	●	●	●	◐	●	◐
GAS & OIL EXTRACTION	◐	●	◐	◐	◐	●	●	●	●
OIL SHALE	N/A	N/A	N/A	N/A	N/A	N/A	N/A	●	N/A

LEGEND: ● - APPLICABLE
 ◐ - SOME REGIONAL CONSTRAINTS
 N/A - NOT APPLICABLE

SOURCE: REGIONAL FOSSIL ENERGY TECHNOLOGY MATRICES

technologies could be varied in alternative scenarios to determine what combination would yield the greatest energy impact as reflected by the indices. Such analyses are provided in Chapter IV in a series of energy-related scenarios to demonstrate how this methodology can be applied.

b. Maximum Potential Impact of a Technology

To perform a technology impact analysis with no specific assumptions as to the amount of each technology that will be introduced, a more general approach is needed. The method used here is based upon the assumption that there is a maximum amount of oil and gas that can be replaced using a technology and that the maximum is related to the sectoral and fuel characteristics of each region. Therefore a technology's potential impact can be measured by the maximum amount of scarce fuel that it could replace in each region. For example, a Coal Liquefaction technology introduced into a region which currently consumes 2 quads of oil in the transportation sector could theoretically replace all that oil and, therefore, would have a maximum potential impact in that regional sector of 2 quads.

If projected energy data were available and a careful market penetration analysis were accomplished, the impact potential of a technology could be assessed quite accurately. Lacking such data, the method discussed here will provide a useful first approximation. For convenience, 1974 energy use patterns and quantities will be used, although the method could be used with any forecast data.

The number of quads of oil and natural gas that could be replaced by a technology's output is the maximum potential impact that technology could have within a region. Assumptions about the limits of substitution are presented below, and the results summarized in Table 12.

High Btu Gasification was assumed to be too expensive to supply the industrial and electric utility sectors. These sectors could either use coal directly or make use of cheaper low Btu gas. Since it would be difficult for the Residential/Commercial sector to switch to other fuels, it is assumed that high Btu gas can replace 100 percent of the natural gas used in this sector.

Low Btu Gasification has minimal application in the Residential/Commercial sector, which is not capable of burning it. It was assumed that

TABLE 12. TECHNOLOGY SUBSTITUTION FACTORS

	<u>TRANS OIL</u>	<u>R/C OIL</u>	<u>R/C GAS</u>	<u>INDUS OIL</u>	<u>INDUS GAS</u>	<u>ELECT OIL</u>	<u>ELECT GAS</u>
HIGH BTU	-	-	1.0	-	-	-	-
LOW BTU	-	-	-	0.5	0.8	-	-
DIRECT COMBUSTION	-	-	-	0.5	0.5	1.0	1.0
ADVANCED POWER SYSTEMS	-	-	-	-	-	1.0	1.0
COAL LIQUEFACTION	1.0	1.0	-	-	-	-	-
GAS/OIL EXTRACTION*	-	-	-	-	-	-	-
OIL SHALE	1.0	1.0	-	-	-	-	-

*Gas and Oil Extraction: Potential increase in oil and gas production = 50 percent (See text).

Source: SCI Estimates

low Btu gas could replace 50 percent of the oil consumed by industry and 80 percent of the natural gas. (Low Btu technologies include the conversion of low Btu to intermediate Btu gas which can be used by industry as a chemical feedstock). As a general rule, low Btu gas was not assumed to be useful to the electric utility sector because the latter could more easily burn coal directly. However, since the West South Central region electric utility sector is currently 90 percent dependent on natural gas, it was assumed that low Btu gas could replace 25 percent of the oil and gas consumed by the WSC electric utility sector.

Direct Combustion includes conventional methods of coal utilization as an alternative to oil and gas consumption. It was assumed that Direct Combustion could replace 100 percent of the electric utility sector consumption of both oil and gas and 50 percent of the industrial sector consumption of oil and gas.

Advanced Power Systems are large facilities and only have application in the electric utility sector. It was assumed that Advanced Power Systems could replace 100 percent of the oil and gas consumption in the electric utility sector.

Coal Liquefaction has application in both the transportation and residential/commercial sectors. It was assumed that Coal Liquefaction could replace 100 percent of the oil consumed in these two sectors. The output of this technology was assumed to be too expensive for the industrial and electric utility sectors which could more easily use coal directly.

Oil Shale has application in both the transportation and residential/commercial sectors and could replace 100 percent of the oil consumed in these two sectors. Because of the cost, liquids from shale were assumed not to be practical for use by the industrial and electric utility sectors.

Gas and Oil Extraction is not treated like the other technologies because it is not a replacement technology but an enhancement of the existing production of oil and gas. The impact of this technology, therefore, is the potential amount of increase in oil and gas production within each region. As a maximum potential impact, it was assumed that oil and gas

production could be increased by as much as 50 percent using this technology. In the Pacific region, which has only begun to exploit Alaskan resources, a production figure equal to 10 percent of known recoverable reserves approximate average national depletion rate of oil and gas) was assumed. The maximum potential impact in the Pacific region was then assumed to be 50 percent of that production figure.

With the present method each technology's maximum potential impact is independent of other technologies and independent of fuel and technology prices. Later revisions to this method could take into account technology substitution and economics. The kinds of insights that can be obtained with the present method are illustrated later.

The technology substitution factors in Table 12 were applied to relevant consumption sectors in each region. For example, 0.5 is the technology substitution factor for Direct Combustion to replace oil consumption in the industrial sector. In the East North Central region, 0.4 quad of oil is used in the industrial sector. Therefore, the maximum potential impact of Direct Combustion in industrial use of oil in the ENC region is 0.2 quad. Such figures can be summed by technology and region, so that a technology's maximum potential impact in a region can be assessed, or the figures can be kept by technology and sector.

For convenience, maximum potential impact results can be displayed as different sized symbols. Also, the regional compatibility symbol can be combined with the maximum potential impact symbol to form a Technology Application Index. Figure 4 shows how these two symbols are combined to develop Technology Application Indices for the East North Central region.

The matrix for the ENC shows that high Btu, low Btu, Direct Combustion Advanced Power Systems and Coal Liquefaction technologies are compatible with regional resources while the Gas and Oil Extraction techniques have regional constraints. Oil Shale technology is not applicable within the region. In addition, the matrix shows that the maximum potential impact would be greatest if Coal Liquefaction products could replace oil and gas. Substantial impact could also be brought about if high Btu, low Btu or Direct Combustion technologies could be introduced into the region. Not only are the technologies compatible with ENC regional resources but there would be a sizeable impact in potential replacement of oil and gas consumption (up to 5.3 quads total).

FIGURE 4. TECHNOLOGY APPLICATION INDICES FOR EAST NORTH CENTRAL REGION

Similar analyses were performed on the application of the technologies to each of the nine census regions. These are described in more detail in Chapter III. The results of the analyses are presented in Figure 5.

c. Application of Technologies to Sectors with High Consumption Indices

A summary of the Consumption and Dependence Index values for all the sectors by region was presented in Table 10. The sectors with the highest Consumption Index values are those using the greatest quantities of scarce oil and natural gas. The application of advanced fossil energy technologies to high Consumption Index value sectors is discussed below.

A list of regional sectors is given in Table 13 in order of decreasing Consumption Index values. The 11 sectors shown have Consumption Index values over 100. The average value of all regional sectors is 100. Consumption of oil and gas in quads in these sectors is also given in Table 13. Technology Substitution Factors from Table 12 were applied to the sectoral oil and gas consumption to determine the maximum potential demand reduction that fossil energy technologies could have on sectoral consumption of critical fuels, with the results shown in Table 13.

Transportation sectors constitute six of the 11 sectors with the highest Consumption Index values in Table 13. At present there is no practical alternative to the use of oil-based fuels in these sectors. However, two fossil energy technologies, Coal Liquefaction and Oil Shale, under development at DOE, show promise for future use in these sectors.

The maximum potential impact of Coal Liquefaction and Oil Shale is large in many regions. Oil Shale technology could be applied only in the Mountain region (where the shales contain more than 25 barrels of liquids per ton), but the product liquids could be transported to the other regions through existing pipelines. Coal Liquefaction has technical and economic constraints to its introduction (through 1985). If the constraints can be overcome, attractive locations for this technology would be in those regions with sufficient coal resources and large potential impact, such as the East North Central, South Atlantic, and Middle Atlantic regions. The liquids could serve a large regional demand and could still be shipped to other regions via existing pipeline systems.

FIGURE 5. **TECHNOLOGY APPLICATION INDICES**

REGION TECHNOLOGY	NEW ENGLAND	MID ATLANTIC	SOUTH ATLANTIC	EAST NORTH CENTRAL	EAST SOUTH CENTRAL	WEST NORTH CENTRAL	WEST SOUTH CENTRAL	MOUNTAIN	PACIFIC
HIGH BTU GASIFICATION	○ N/A	●	●	●	●	●	◐	●	◐
LOW BTU GASIFICATION	◐	●	●	●	●	●	◐	●	◐
DIRECT COMBUSTION	◐	●	●	●	●	●	◐	●	◐
ADVANCED POWER SYSTEM	◐	●	●	●	●	●	◐	●	◐
COAL LIQUEFACTION	○ N/A	●	●	●	●	●	◐	●	◐
GAS & OIL EXTRACTION	◐	●	◐	◐	◐	●	●	●	●
OIL SHALE	○ N/A	○ N/A	○ N/A	○ N/A	○ N/A	○ N/A	○ N/A	●	○ N/A

LEGEND:

NOTE: SEE TEXT FOR FULL EXPLANATION OF SYMBOLS SOURCE: SCI

TABLE 13. SECTORS WITH HIGH CONSUMPTION OF OIL AND GAS

						MAXIMUM POTENTIAL IMPACT						
U	REGION	SECTOR	CONSUMPTION (QUADS)		TOTAL	HBTU	LBTU	D.C.	ADV. PWR.	LIQ.	G&O EXT.	OIL SHALE
			OIL	GAS								
394	WSC	INDUS	1.1	4.7	5.8		4.3	2.9			5.8	
236	ENC	R/C	1.2	2.3	3.5	2.3				1.2	-	1.2
211	ENC	TRANS	3.0	.1	3.1					3.0	-	3.0
191	SA	TRANS	2.7	0	2.7					2.7	-	2.7
188	MA	R/C	1.7	1.1	2.8	1.1				1.7	-	1.7
170	P	TRANS	2.4	0	2.4					2.4	2.4	2.4
169	WSC	TRANS	2.2	.2	2.4					2.4	2.4	2.2
165	MA	TRANS	2.4	0	2.4					2.4	-	2.4
152	WSC	ELEC	.2	2.1	2.3			2.3	2.3			
144	ENC	INDUS	.4	1.7	2.1		1.6	1.1			-	
110	WNC	TRANS	1.5	.1	1.6					1.5	0.8	1.5

Source: SCI Calculations

The West South central industrial sector is by far the largest sector-consumer of critical energy fuels, almost 5.8 quads. Natural gas consumption is 80 percent of this sector total.

The West South Central region produces huge quantities of oil and gas. Gas and Oil Extraction technologies, therefore, are naturals for application in this region. Coal-using technologies, such as low Btu Gasification and Direct Combustion, have regional constraints because of limited coal reserves and transportation facilities. Coal could be transported from the adjacent Mountain and East South Central regions, however, to allow Direct Combustion technology to be applied in the WSC region. Coal also could be imported to produce low Btu gas, but it would make more economic sense to burn the coal directly and use natural gas in those industrial processes where gas is needed. Similarly, long distance transportation of low Btu gas produced in another region would be too expensive.

The East North Central and Middle Atlantic regions are populous areas with high oil and gas consumption in the residential/commercial sector. Both regions have sizable coal reserves so High Btu Gasification and Coal Liquefaction technologies could be applied if technical and economic constraints are overcome. Oil Shale technology could produce liquids in the Mountain region which could replace oil in the existing pipeline network. Gas and Oil Extraction technologies would have minimal impact in either region because of low production of gas and oil, but offshore technologies may prove valuable in the Middle Atlantic region if offshore reserves prove to be adequate.

The West South Central electric utility sector is unique among the regions because of its high consumption of natural gas to produce electric power. This is due to ready availability of gas-producing fields within the region. Direct Combustion or Advanced Power Systems technologies could be applicable to this sector, but regional resources of coal are not adequate to support the technologies. Coal could be imported into the region to support the technologies, or electric power produced from coal could be imported into the WSC region from another region.

Either Low Btu Gasification or Direct Combustion technologies could be applied in the East North Central industrial sector to reduce dependence on oil and natural gas. Abundant coal reserves make this region attractive for introducing either or both technologies.

III. ENERGY CHARACTERISTICS AND FOSSIL TECHNOLOGY APPLICATIONS FOR EACH REGION OF THE U.S.A.

Energy supply/demand characteristics for each of the nine census regions and the dependence of individual consuming sectors on critical oil and gas supplies are discussed in this chapter. The potential application of fossil energy technologies to reduce dependence on critical fuel supplies is analyzed with regard to regional constraints.

The Supply/Demand Profile, the Regional Energy Descriptive Matrix, and the Fossil Energy Technology Matrix are presented for each region. A detailed analysis is made of the energy characteristics of each region using the Technology Application Index Matrix (Figure 5) and the Technology Substitution Factors (Table 12) from Chapter II. A national energy overview is presented before the regional analyses.

A. NATIONAL ENERGY OVERVIEW

In 1974, the U.S. consumed approximately 73 quads (1 quad = 1015 Btus) of primary energy resources (Table 14). National production of energy was approximately 61 quads. The difference, about 16 percent of the total U.S. energy consumption, was made up by net imports.

The nation's dependence on foreign sources of petroleum is particularly significant. Petroleum products supply about 46 percent of the nation's energy needs or over 33 quads. National petroleum production was less than 19 quads. This resulted in a reliance on 15 quads of imported oil, approximately 44 percent of the oil consumed in 1974.

Even though 1974 U.S. production of natural gas, 24 quads, exceeded consumption, 22 quads, known recoverable reserves of natural gas, like petroleum, are rapidly being depleted. Thus, the most sought after energy resources, natural gas and petroleum, have the smallest reserve base and are being depleted most rapidly.

Conversely, the nation's coal reserves are among the largest in the world. U.S. coal resources could supply all present U.S. energy requirements for over 100 years, although coal now provides only 18 percent of our national energy needs. The fossil energy technologies associated with coal gasification and liquefaction, and advanced power systems based on coal are of particular interest for this reason.

TABLE 14. UNITED STATES SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																		NET IMPORTS (FOREIGN & DOMESTIC)					
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWH	NUCLEAR ELECTRIC 10 ⁶ KWH	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S		
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP	
REGIONAL TOTALS	436,725,500	34,241,485	236,964,413	1,239,600	600,000,000	261	768	FOSSIL 2,456	610,021	3,202,585	21,600,522	300,466	112,740		COAL	17,018.8	3689.2	158.6	8375.2	118.8	12341.8	57	30	1	68	1	100%	96	19	1	42	37	18					
								NUCLEAR 36							OIL	3190.7	6115.1	3480.8	200.8	30006.2	3	10	20	12	1	100%	4	52	54	18	63	44	-2,608.4	11431.2	-1710.2	6947.5		
								HYDRO 1152	15,120.7	18,575.0	23,695.8	3076.5	1,201.8	61,669.7	NG	10283.6	7495.9	3523.3		21985.6	3	47	34	16		100%	0	13	27									
	9,911,294.0	198,600.6	259,950.0	266,514.0	3,290,000										ELECT*	2667.4	3723.2		(6406.6)	0	42	58			100%													
															HYDRO			3076.5		3076.5				100		100%					16		4					
															NUCLEAR			1201.8		1201.8				100		100%					6		2	-21%	38%	-8%	10%	
															TOTAL	17701.6	17163.5	13769.6	19657.5	319.6	68611.9	26	25	20	29	0	100%	100%	100%	100%	100%	100%	100%					
UNDISTRIBUTED ITEMS	-100	8,471	168,084	40,400	0	0	0	FOSSIL 0	2	0	0	16,474	837		COAL	2.7	440.0	138.9	144.4	-118.8	506.6						100%											
								NUCLEAR 0							OIL	2718.7	-16.3	-6	44.5	3461.1						100%												
								HYDRO 0	-633.8	0	-6.5	232.5	9.2	562.6	NG	-265.4	22.1	-11.8	-253							100%												
	-22.7	49.1	184.4	8,686.0	0										ELECT*	(2.6)	(2.8)		(5.4)						100%													
															HYDRO			199.5		232.5					100%													
															NUCLEAR			9.2		9.2					100%													
															TOTAL	718.9	2926.3	144.7	340.7	-74.3	4056.3						100%	100%	100%	100%	100%	100%	100%	100%				
U.S. TOTAL	436,725,400	34,249,956	237,132,497	1,280,000	600,000,000	261	768	FOSSIL 2456	610,023	3,202,585	21,600,522	316,920	113,577		COAL	2.1	4129.2	297.5	8519.6	0	12948.4		32	2	66	0	100%		18	2	43	0	18					
								NUCLEAR 36							OIL	5909.4	6098.8	3480.2	245.3	33467.3	53	18	18	10	1	100%	96	26	34	17	100	46	-1374.4	14892.3	-1956.8	11561.1		
								HYDRO 1152	14,486.9	18,575.0	23,689.3	3,309.0	1,211.0	61,271.2	NG	10018.2	7518.0	3511.5	0	21732.5	3	46	35	16		100%	4	44	43	18		30						
															ELECT*	(16.0)	(2670.0)	(3726.0)		(6412.0)	0	42	58			100%	0	12	21									
															HYDRO			3276.0		3309.0		1		99		100%					16		4					
															NUCLEAR			1211.0		1211.0				100		100%					6		2	-11%	44%	9%	16%	
															TOTAL	18420.5	20089.8	13914.3	19998.2	245.3	72668.2	25	28	19	28	0	100%	100%	100%	100%	100%	100%	100%					

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

Oil shale is another potential alternative to petroleum imports. Oil shale reserves are approximately one-third the size of the nation's coal reserves. If appropriate technologies were available, oil shale could potentially supply large quantities of petroleum products for transportation and residential home heating uses.

For purposes of regional energy analysis, the U.S. was divided into nine census regions (Figure 6). The nine regional supply/demand profiles presented in Section B, below, are summarized in Table 15. Sums of the regions' data are called "Regional Totals" in Table 14. Differences between "Regional Totals" and "U.S. Total" are termed "Undistributed Items". This category includes fuels of unknown geographical distribution.

Most of the "Undistributed Items" are of minor importance, with the exception of oil consumption (approximately 3.5 quads). Most of this undistributed oil consumption, 2.7 quads, occurs in the industrial sector. Total undistributed oil consumption represents over 10 percent of total national oil consumption, and undistributed industrial consumption represents about 46 percent of national industrial oil consumption. Subsequent analyses, which are based on regional profiles, do not include these undistributed oil consumption data. Hence the energy indices calculated for regions, and in particular industrial sectors within regions, are biased downward in terms of dependence on oil.

The U.S. energy supply situation in 1974, as indicated in Tables 16 and Figure 7, is regionally imbalanced. The West South Central region has the largest reserves and production of oil and gas. The Mountain (40 percent) and the East North Central (23 percent) regions have the largest coal reserves, while the East South Central (28 percent) and the South Atlantic (25 percent) dominate in coal production.

B. REGIONAL ENERGY CHARACTERISTICS

1. New England Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the New England (NE) region in 1974 is given in Table 17. New England consumes less than 5 percent of the energy used in the country. This relatively low energy consumption is reflected in a Consumption Index value of 45 in Table 18. It is the lowest regional

**FIGURE 6. REGIONAL DIVISIONS
OF THE UNITED STATES**

TABLE 15. REGIONAL SUPPLY/DEMAND PROFILE

CHARACTERISTICS REGION	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																		NET IMPORTS (FOREIGN & DOMESTIC)				
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ CU.FT.	URANIUM U ₃₀₈ 10 ³ LBS	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ CU.FT.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S):						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP
NEW ENGLAND	0	0	0	0	0	2	0	FOSSIL 137	0	0	0	4,753	16,912	218.3	COAL	—	5.3	.8	46.7	1.5	54.3	—	10	1	86	3	100%	—	2	0	6	28	2	54.3	2290.3	267.4	2612.0
								NUCLEAR 6							NG	782.5	181.3	860.8	461.9	3.8	2290.3	34	8	38	20	0	100%	100	57	70	63	72	81				
								HYDRO 136	0	0	0	37.9	180.4	218.3	ELECT*	(.1)	(79.9)	(172.0)	—	—	(252.0)	0	32	68	—	—	100%	0	25	14	—	—	—				
	0	0	0	0	0										HYDRO	—	—	—	37.9	—	37.9	—	—	—	100	—	100%	—	—	—	5	—	1				
MIDDLE ATLANTIC	31,000,600	61,312	1,657,691	0	0	18	2	FOSSIL 225	87,079	4,374	87,627	29,746	19,943	2,992.5	COAL	—	971.2	9.7	1,038.0	105.2	2,124.1	—	46	0	49	5	100%	—	44	0	40	30	22	-193.9	5338.8	1564.5	6709.4
								NUCLEAR 8							NG	2,352.1	378.9	1,660.2	980.9	12.1	5,364.2	44	7	31	18	0	100%	99	17	51	37	10	55				
								HYDRO 224	2,318.0	25.4	96.2	340.3	212.6	2,992.5	ELECT*	(12.8)	(351.0)	(500.3)	—	—	(864.1)	1	41	58	—	—	100%	0	16	16	—	—	—				
	813,337.0	355.6	1818.5	0	0										HYDRO	—	—	—	340.3	—	340.3	—	—	—	100	—	100%	—	—	—	13	—	4				
SOUTH ATLANTIC	44,319,900	334,919	2,619,154	0	0	9	5	FOSSIL 273	139,124	39,019	247,672	17,369	24,931	4,652.9	COAL	—	513.5	36.6	1,794.2	1.9	2,346.2	—	22	2	76	0	100%	—	26	2	52	6	26	-1364.1	4,655.0	1,242.0	4,532.9
								NUCLEAR 4							NG	2,711.8	444.8	718.0	978.4	28.3	4,881.3	55	9	15	10	1	100%	99	22	36	28	94	53				
								HYDRO 129	3,710.3	226.3	271.6	178.8	265.9	4,652.9	ELECT*	(0.8)	(365.5)	(685.1)	—	—	(1,051.4)	0	35	65	—	—	100%	0	18	34	—	—	—				
	1,184,595.4	1,942.5	2,873.1	0	0										HYDRO	—	—	—	178.8	—	178.8	—	—	—	100	—	100%	—	—	—	5	—	2				
EAST NORTH CENTRAL	97,422,800	390,310	3,277,019	0	0	31	8	FOSSIL 428	127,352	59,581	162,000	3,318	28,264	3,854.7	COAL	—	1452.2	71.6	2830.6	8.7	4363.1	—	33	2	65	0	100%	—	35	2	80	17	32	1369.4	4473.4	4032.4	9875.2
								NUCLEAR 8							NG	2,989.6	420.1	1,153.0	214.7	41.5	4818.9	62	9	24	4	1	100%	98	10	28	6	83	35				
								HYDRO 162	2,993.7	345.5	178.6	35.6	301.3	3,854.7	ELECT*	(1.4)	(590.5)	(647.2)	—	—	(1239.1)	0	48	52	—	—	100%	0	14	15	—	—	—				
	2,263,695.2	2,263.8	3,543.4	0	0										HYDRO	—	—	—	35.6	—	35.6	—	—	—	100	—	100%	—	—	—	1	—	0				
EAST SOUTH CENTRAL	29,509,100	366,698	2,430,792	0	0	14	12	FOSSIL 79	164,561	72,708	178,545	25,509	6,289	5,114.3	COAL	—	379.7	13.9	1,221.0	0	1,614.6	—	24	1	75	0	100%	—	27	1	75	0	35	-2,586.2	1,141.9	890.5	-553.8
								NUCLEAR 1							NG	1,124.6	107.1	250.2	70.1	11.7	1,563.7	72	7	16	4	1	100%	90	8	28	4	100					
								HYDRO 53	4,200.8	421.8	195.9	228.8	67.0	5,114.3	ELECT*	(0)	(358.7)	(278.8)	—	—	(637.5)	0	56	44	—	—	100%	0	26	31	—	—	—				
	736,316.4	2,126.9	2,666.5	0	0										HYDRO	—	—	—	228.8	—	228.8	—	—	—	100	—	100%	—	—	—	14	—	5				
WEST NORTH CENTRAL	30,191,300	594,680	12,192,022	0	0	19	36	FOSSIL 709	13,393	88,549	920,559	12,993	9,290	2,031.7	COAL	—	123.4	13.1	737.8	0.3	874.6	—	14	2	84	0	100%	—	12	1	52	1	16	638.2	1,662.9	1,046.8	3,347.9
								NUCLEAR 5							NG	1,466.0	123.7	524.4	38.8	23.5	2,176.4	67	6	24	2	1	100%	93	12	31	3	99	41				
								HYDRO 62	236.4	513.5	1,009.8	173.0	99.0	2,031.7	ELECT*	(0)	(147.1)	(266.9)	—	—	(412.9)	0	36	64	—	—	100%	0	13	15	—	—	—				
	529,297.3	3,449.1	13,374.6	0	0										HYDRO	—	—	—	173.0	—	173.0	—	—	—	100	—	100%	—	—	—	12	—	3				
WEST SOUTH CENTRAL	5,231,800	16,566,733	158,096,878	87,300	0	84	567	FOSSIL 296	10,495	2,193,762	17,687,346	9,484	361	32,404.9	COAL	—	49.2	0.1	75.8	0	125.1	—	39	0	61	0	100%	—	1	0	3	0	1	-47.4	-8771.8	-11743.4	-20,562.6
								NUCLEAR 1							NG	2235.1	1118.2	397.1	166.5	35.2	3952.1	57	28	10	4	1	100%	91	18	26	7	100					
								HYDRO 42	172.5	12,723.9	19,403.0	101.7	3.8	32,404.9	ELECT*	(0.1)	(324.8)	(431.4)	—	—	(756.3)	0	43	57	—	—	100%	0	5	28	—	—	—				
	94,676.3	96,087.0	173,432.3	18,877.0	0										HYDRO	—	—	—	101.7	—	101.7	—	—	—	100	—	100%	—	—	—	4	—	1				
MOUNTAIN	185,388,800	2,275,698	19,676,653	1,151,800	600,000,000	38	92	FOSSIL 168	63,404	350,986	1,821,684	32,243	0	5,798.6	COAL	—	121.1	12.1	571.5	0	704.7	—	17	2	81	0	100%	—	14	1	46	0	19	-687.1	-637.7	-747.3	-2,072.1
								NUCLEAR 0							NG	935.4	143.5	221.7	76.8	20.5	1,397.9	67	10	16	5	2	100%	93	16	25	6	100					
								HYDRO 167	1,391.8	2,035.6	1,998.4	372.8	0	5,798.6	ELECT*	(.1)	(109.5)	(198.0)	—	—	(307.6)	0	36	64	—	—	100%	0	12	23	—	—	—				
	3,979,737.4	13,199.1	21,585.4	247,637.0	3,290,000										HYDRO	—	—	—	372.8	—	372.8	—	—	—	100	—	100%	—	—	—	30	—	10				
PACIFIC	13,601,200	13,651,135	37,061,204	0	0	46	46	FOSSIL 141	4,613	393,606	494,289	165,031	6,750	4596.5	COAL	—	73.8	.7	59.4	0	133.9	—	55	1	44	0	100%	—	4	0	2	0	2	42.2	1,278.5	1,736.8	3,057.5
								NUCLEAR 3							NG	2,421.6	273.1	329.7	512.8	24.2	3,561.4	68	8	9	14	1	100%	99	17	18	20	100					
								HYDRO 285	91.7	2,282.9	542.2	1,607.7	72.0	4596.5	ELECT*	(.7)	(340.5)	(544.3)	—	—	(855.5)	0	38	62	—	—	100%	0	21	30	—	—	—				
	304,039.0	79,176.5	40,656.2	0	0										HYDRO	—	—	—	1,607.7	—	1,607.7	—	—	—	100	—	100%	—	—	—	62	—	21				

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

FIGURE 7. REGIONAL SHARES OF U.S. FOSSIL ENERGY RESERVES AND PRODUCTION - 1974

COAL

OIL

GAS

TABLE 16

REGIONAL PERCENTAGES OF U.S. FOSSIL
ENERGY RESERVES AND PRODUCTION 1974

	<u>PERCENT OF NATIONAL RESERVES</u>			<u>PERCENT OF NATIONAL PRODUCTION</u>		
	<u>COAL</u>	<u>OIL</u>	<u>GAS</u>	<u>COAL</u>	<u>OIL</u>	<u>GAS</u>
NEW ENGLAND	0.0	0.0	0.0	0.0	0.0	0.0
MIDDLE ATLANTIC	8.3	0.2	0.7	15.3	0.1	0.4
SOUTH ATLANTIC	12.0	1.0	1.1	24.5	1.2	1.1
EAST NORTH CENTRAL	22.8	1.1	1.4	19.8	1.9	0.8
EAST SOUTH CENTRAL	7.4	1.1	1.0	27.8	2.3	0.8
WEST NORTH CENTRAL	5.3	1.7	5.2	1.6	2.8	4.3
WEST SOUTH CENTRAL	1.0	48.4	66.7	1.1	68.5	81.9
MOUNTAIN	40.2	6.6	8.3	9.2	11.0	8.4
PACIFIC	<u>3.1</u>	<u>39.9</u>	<u>15.6</u>	<u>0.6</u>	<u>12.3</u>	<u>2.3</u>
U.S.	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 17. NEW ENGLAND REGION
SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																			NET IMPORTS (FOREIGN & DOMESTIC)										
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM 10 ³ LBS.	OIL SHALE 10 ¹ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)							SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S							
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP							
CONNECTICUT	0	0	0	0	0	0	0	FOSSIL 29	0	0	0	422	7,970	89.8	COAL	—	1.6	0	3.7	.2	5.5	—	29	0	67	4	100%	—	2	0	1	15	1	5.5	563.9	68.4	637.8							
	NUCLEAR 2																																											
	HYDRO 15	0	0	0	4.8			85.0	89.8	HYDRO	—	—	—	4.8	—	4.8	—	—	—	—	—	—	—	—	—	—	100	—	—	—	2	—	1					100%	100%	100%	88%			
	NUCLEAR	—	—	—	85.0			—	85.0	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	—	100	—	—	—	32	—	12					100%	100%	100%	100%			
MAINE	0	0	0	0	0	0	0	FOSSIL 25	0	0	0	1,756	3,574	51.1	COAL	—	1.4	.2	0	.2	1.8	—	82	4	0	4	100%	—	3	0	0	50	1	1.8	246.5	0	248.3							
	NUCLEAR 1																																											
	HYDRO 38	0	0	0	13.0			38.1	51.1	HYDRO	—	—	—	13.0	—	13.0	—	—	—	—	—	—	—	—	—	—	100	—	—	—	17	—	4					100%	100%	100%	83%			
	NUCLEAR	—	—	—	38.1			—	38.1	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	—	100	—	—	—	50	—	13					100%	100%	100%	100%			
MASSACHUSETTS	0	0	0	0	0	0	0	FOSSIL 49	0	0	0	359	2,885	34.5	COAL	—	2.0	.6	15.8	.7	19.1	—	10	3	83	4	100%	—	2	0	5	30	2	19.1	1,135.3	160.6	1,315.0							
	NUCLEAR 2																																											
	HYDRO 26	0	0	0	3.7			30.8	34.5	HYDRO	—	—	—	3.7	—	3.7	—	—	—	—	—	—	—	—	—	—	100	—	—	—	1	—	0					100%	100%	100%	97%			
	NUCLEAR	—	—	—	30.8			—	30.8	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	—	100	—	—	—	10	—	2					100%	100%	100%	100%			
NEW HAMPSHIRE	0	0	0	0	0	1	0	FOSSIL 10	0	0	0	1,292	0	9.5	COAL	—	.2	0	24.2	.1	24.5	—	1	0	99	0	100%	—	1	0	50	25	14	24.5	133.5	14.0	172.0							
	NUCLEAR 0																																											
	HYDRO 13	0	0	0	9.5			0	9.5	HYDRO	—	—	—	9.5	—	9.5	—	—	—	—	—	—	—	—	—	—	100	—	—	—	20	—	5					100%	100%	100%	95%			
	NUCLEAR	—	—	—	0			—	0	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	—	100	—	—	—	0	—	0					100%	100%	100%	100%			
RHODE ISLAND	0	0	0	0	0	1	0	FOSSIL 9	0	0	0	4	0	.1	COAL	—	0	0	1.7	.1	1.8	—	0	0	94	6	100%	—	0	0	11	25	1	1.8	144.0	24.4	170.2							
	NUCLEAR 0																																											
	HYDRO 1	0	0	0	.1			0	.1	HYDRO	—	—	—	.1	—	.1	—	—	—	—	—	—	—	—	—	—	100	—	—	—	0	—	0					100%	100%	100%	100%			
	NUCLEAR	—	—	—	0			—	0	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	—	100	—	—	—	0	—	0					100%	100%	100%	100%			
VERMONT	0	0	0	0	0	0	0	FOSSIL 15	0	0	0	920	2,483	33.3	COAL	—	.1	0	1.3	.2	1.6	—	6	0	81	13	100%	—	1	0	4	40	1	1.6	67.1	0	68.7							
	NUCLEAR 1																																											
	HYDRO 43	0	0	0	6.8			26.5	33.3	HYDRO	—	—	—	6.8	—	6.8	—	—	—	—	—	—	—	—	—	—	100	—	—	—	19	—	7					100%	100%	100%	67%			
	NUCLEAR	—	—	—	26.5			—	26.5	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	—	100	—	—	—	75	—	26					100%	100%	100%	100%			
NEW ENGLAND	0	0	0	0	0	2	0	FOSSIL 137	0	0	0	4,753	16,912	218.3	COAL	—	5.3	.8	46.7	1.5	54.3	—	10	1	86	3	100%	—	2	0	6	28	2	54.3	2,290.3	267.4	2,612.0							
	NUCLEAR 6																																											
	HYDRO 136	0	0	0	37.9			180.4	218.3	HYDRO	—	—	—	37.9	—	37.9	—	—	—	—	—	—	—	—	—	—	100	—	—	—	5	—	1					100%	100%	100%	92%			
	NUCLEAR	—	—	—	180.4			—	180.4	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	—	100	—	—	—	25	—	6					100%	100%	100%	100%			
															TOTAL	783.2	239.8	1,065.3	736.7	5.3	2,830.3	28	8	38	26	0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

TABLE 18
REGIONAL ENERGY MATRIX

NEW ENGLAND

INDEX	TOTAL	SECTOR	C	O	G	N	H
U CONSUMPTION	45		0	40	4	1	0
			CONSUMPTION (10 ¹⁵ BTU)				
		TRANS 54	0	0.8	0	-	-
		INDUS 16	0	0.2	0	-	-
		R/C 74	0	0.9	0.2	-	-
		ELEC 35	0	0.5	0	0.2	0
D DEPENDENCE	121		0	107	12	2	0
			DEPENDENCE (PERCENT)				
		TOTAL	2	81	10	6	1
		TRANS 132	0	100	0	-	-
		INDUS 129	2	76	22	-	-
		R/C 132	0	81	19	-	-
		ELEC 91	6	63	1	25	5
P POPULATION INDUCED CONSUMPTION	57		0	51	5	1	0
			DISTRIBUTION (PERCENT)				
			2	83	9	5	1
I INDUSTRY INDUCED CONSUMPTION	22		0	18	3	1	0
			DISTRIBUTION (PERCENT)				
			4	69	12	12	3

consumer of coal, natural gas and electricity. However, oil dependency of 81 percent, which is higher than any other region. New England, moreover, is the fourth highest region in oil imports.

The NE Dependence index value (121) is second only to the West South Central region. All four consuming sectors in New England have a higher dependence on oil than they do in any other region. Massachusetts and Connecticut account for 74 percent of the petroleum consumed in the region.

Regional/Resources and Applicable Technologies

The NE region has no known recoverable oil, gas or coal resources. Deteriorating railroads and marine facilities present a serious problem with regard to the transport of coal within the region. Spur tracks have been ripped up and coal-handling facilities and docks are in need of repair. New England does have a number of ports (e.g., Boston, Portland) that, with improvement, could be utilized to receive coal.

The Fossil Energy Technology Matrix for New England is presented in Table 19. The implementation of coal conversion technologies, such as Direct Combustion, in the region would be constrained by the region's ability to transport and handle large quantities of coal. The oil pipeline network in New England is limited to interconnections between the major cities (Boston, Worcester, New Haven, Hartford and Providence). Natural gas distribution systems in New England exist only in Massachusetts, Connecticut and Rhode Island.

High Btu Gasification is considered not applicable in New England as it would be preferable to convert coal to gas in other regions which have adequate coal reserves and transport the synthetic gas in existing pipelines to New England. Similarly, Coal Liquefaction and Oil Shale conversion processes are considered not directly applicable since they would be located elsewhere. The product fuels, however, would be used in New England. Direct Combustion, Low Btu Gasification and Advanced Power Systems technologies will have limited application, depending on the future development of requisite transportation systems.

TABLE 19. NEW ENGLAND REGION
FOSSIL ENERGY TECHNOLOGY MATRIX

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS							APPLICATION INDEX	
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL			REMARKS			
														AIR	WATER	SOLID WASTE				
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SNG 250 x 10 ⁶ CuFt/day 91,250 x 10 ⁶ Btu/year 1,000 Btu/CuFt 91.25 x 10 ¹² Btu/year OTHER PRODUCTS Ammonia - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY NAPHTHA - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE			NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 43 TONS/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF CAKING COALS WHICH AGGLOMERATE IN GASIFIERS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	N/A
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CuFt/day 521,714 x 10 ⁶ Btu/year 175 Btu/CuFt 91.3 x 10 ¹² Btu/year OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6488 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5279 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE			NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 2% SOx 30-40 HC 3 CU 2	BOD 30PPM COD 25PPM TDS 250PPM	865 TONS/DAY (4,000 TONS/DAY OF SPENT DOLOMITE IF USED)	• UTILIZATION OF CAKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS OF SCALE-UP. • HIGH CAPITAL INVESTMENT.	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (37 MW) 720x10 ³ KWHR/DAY 283x10 ⁶ KWHR/DAY 3,432 Btu/KWHR 0.9 x 10 ¹² Btu/year OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE			NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES yr/10 ¹² BTU	UNKNOWN	\$ 20x10 ⁶ to \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 Btu/KWHR	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TON/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	17 TONS/DAY	• FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • SORBENT REGENERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.B. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWHR/DAY 5,563 x 10 ⁶ KWHR/YEAR 3,432 Btu/KWHR 19.2x10 ¹² Btu/YR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE			NONE	43.8x10 ⁶ KWHR/YR	6.1 MGD	DOLOMITE - 486 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE yr/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGERS LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ¹⁰ Btu/BARREL 207.0 x 10 ¹² Btu/year OTHER PRODUCTS Ammonia - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE			NONE	1,261x10 ⁶ KWHR/YR	3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT MOLYBDENUM 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 63%	1990 - 2010	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	BOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.	N/A
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL .09 x 10 ³ BARRELS/DAY 178 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ Btu/BARREL 1 x 10 ¹² Btu/year OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE			NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - yr/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 30% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(TONS/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. • RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAR SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ¹⁰ Btu/BARREL 211.7 x 10 ¹² Btu/year OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE			132x10 ³ TONS/DAY 48,180x10 ³ TONS/YR	1,489x10 ⁶ KWHR/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 67%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	AMINES 1900PPM CARBONATES 520PPM CHLORIDES 330PPM CHROMATES 130PPM CYANIDES 50PPM ORGANIC ACIDS 1000PPM PHENOLS 80PPM	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A

REGIONAL RESOURCES AND CHARACTERISTICS	REGIONAL CONSUMPTION (1974)	RESERVES - 0			AVAILABILITY - N/A			RESERVES - 0			DISTRIBUTED	DEPLETION RATE 0.6% CONSUMPTION (M.G.D.) 475	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	LEGEND: ● APPLICABLE ○ SOME REGIONAL CONSTRAINTS N/A NOT APPLICABLE
		CHARACTERISTICS	UNDERGROUND	SURFACE	CHARACTERISTICS	UNDERGROUND	SURFACE	CHARACTERISTICS	UNDERGROUND	SURFACE								
COAL	54.2 x 10 ¹² Btu	10 ¹⁰ TONS	0	0	TRAIN	0	0	1,487	0	0	73,852 x 10 ⁶ KWHR	172						
OIL	2,290.3 x 10 ¹² Btu	SULFUR CONTENT <1% 1.1% - 1.5% > 1.5% UNKNOWN	A/A	N/A	UNIT TRAIN	0	0	(NOT AVAIL)	0	0		216						
NATURAL GAS	267.4 x 10 ¹² Btu				BARGE	0	0	568	0	0		11						
ELECTRIC POWER	252.0 x 10 ¹² Btu				TRUCK	0	0	0	0	0		18						
		COAL TYPE			TOTAL	0	0	2055				56						
		ANTHRACITE	N/A	N/A	REMARKS - WISCONSIN - NO COAL RESERVES													
		BITUMINOUS			MICHIGAN - SMALL COAL RESERVES													
		LIIGNITE			NO PRODUCTION													

It would be possible to apply Gas and Oil Extraction Technologies if offshore reserves prove adequate. At present, the extent of these offshore reserves is not known.

Consuming Sectors

A. Residential/Commercial

The residential/commercial sector in New England consumes a greater proportion of regional energy than any other residential/commercial sector in the nation. It consumes 41 percent of the total energy and 39 percent of the oil used in New England. The high consumption of oil (0.9 quad) is due to its extensive use for space heating. Due to a lack of regional resources, New England must either continue to import foreign oil for home heating or import liquids from an alternative source. Coal Liquefaction and Oil Shale technologies, located outside the region and providing petroleum substitutes through existing pipelines, could reduce the dependence of the R/C sector on foreign oil. However, technological, economic and environmental constraints associated with these technologies will have to be overcome before these technologies will be available. High Btu Gasification products could be transmitted to the southern portion of New England where 0.2 quad of natural gas were consumed in 1974.

B. Electric Utility

Although electric utilities in New England use only 4 percent of the total energy consumed by electric utilities in the country, this sector uses 17.6 percent of the oil consumed by the U.S. electric power sector. Electric utilities in New England are 63 percent dependent on oil. If coal could be transported to power plant sites, its increased use for electric power generation would reduce the region's dependence on foreign imports. The use of coal-oil slurries may have application in this respect. And when they become available, Advanced Power Systems will have an equivalent potential for reducing oil consumption by the Electric Utilities.

C. Industrial

New England's industrial sector, which is 76 percent dependent on oil, uses 6.3 percent of the oil used by industry across the nation. An oil embargo could adversely affect New England's industry because of its high dependence on oil. The introduction of coal-based technologies (e.g.,

**TABLE 20. MIDDLE ATLANTIC REGION
SUPPLY/DEMAND PROFILE**

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																		NET IMPORTS (FOREIGN & DOMESTIC)				
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM U ₃₀₈ 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP
NEW JERSEY	0	0	0	0	0	5	0	FOSSIL 41	0	0	0	-285	3,673		COAL	—	3.7	.2	70.3	2.9	77.1	—	5	0	91	4	100%	—	2	0	19	69	4	77.1	1,277.1	279.4	1,633.6
								NUCLEAR 1							OIL	518.2	114.3	383.6	259.7	1.3	1,277.1	41	9	30	20	0	100%	100	46	56	68	31	77				
								HYDRO 2	0	0	0	-3.3	39.2	35.9	NG	.6	65.2	198.1	15.5	—	279.4	0	23	71	6	—	100%	0	26	29	4	—	17				
	0	0	0	0	0			ELECT*	(0)	(63.4)	(102.3)	—	—	(165.7)	0	38	62	—	—	—	100%	0	26	15	—	—	100%	0	26	15	—	—	—				
NEW YORK	0	10,898	165,546	0	0	2	0	FOSSIL 86	0	896	4,990	28,639	9,272		COAL	—	202.6	1.9	165.2	16.1	385.8	—	53	0	43	4	100%	—	38	0	14	83	10	385.8	2,587.5	642.4	3,615.7
								NUCLEAR 3							OIL	1,054.3	90.8	892.8	551.4	3.4	2,592.7	41	4	34	21	0	100%	99	17	55	47	17	64				
								HYDRO 113	0	5.2	5.5	328.8	98.8	438.3	NG	3.1	118.1	487.4	39.3	—	647.9	0	18	75	6	—	100%	0	23	30	3	—	16				
	0	63.2	181.6	0	0			ELECT*	(9.4)	(116.7)	(234.0)	—	—	(360.9)	3	32	65	—	—	—	100%	1	22	15	—	—	100%	1	22	15	—	—	—				
PENNSYLVANIA	31,000,600	50,414	1,492,145	0	0	11	2	FOSSIL 98	87,079	3,478	82,637	1,392	6,998		COAL	—	764.9	7.6	802.5	86.2	1,661.2	—	46	1	48	5	100%	—	53	1	76	92	42	-656.8	1,474.2	642.7	1,460.1
								NUCLEAR 4							OIL	779.6	173.8	383.8	149.8	7.4	1,494.4	52	11	26	10	1	100%	97	12	41	14	8	38				
								HYDRO 9	2,318.0	20.2	90.7	14.8	74.6	2,518.3	NG	21.4	321.7	382.2	8.1	—	733.4	3	44	52	1	—	100%	3	22	41	1	—	18				
	818,937.0	292.4	1,636.9	0	0			ELECT*	(3.4)	(170.9)	(163.2)	—	—	(337.5)	1	51	48	—	—	—	100%	0	12	17	—	—	100%	0	12	17	—	—	—				
MIDDLE ATLANTIC	31,000,600	61,312	1,657,691	0	0	18	2	FOSSIL 225	87,079	4,374	87,627	29,746	19,943		COAL	—	971.2	9.7	1,038.0	105.2	2,124.1	—	46	0	49	5	100%	—	44	0	40	90	22	-193.0	5,338.8	1,564.5	6,709.4
								NUCLEAR 8							OIL	2,352.1	378.9	1,660.2	960.9	12.1	5,364.2	44	7	31	18	0	100%	99	17	51	37	10	55				
								HYDRO 224	2,318.0	25.4	96.2	340.3	212.6	2,992.5	NG	25.1	505.0	1,067.7	62.9	—	1,660.7	2	30	64	4	—	100%	1	23	33	2	—	17				
	818,937.0	355.6	1,818.5	0	0			ELECT*	(12.8)	(351.0)	(500.3)	—	—	(864.1)	1	41	58	—	—	—	100%	0	16	16	—	—	100%	0	16	16	—	—	—				
*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS																																					

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

SOURCE: AND U.S. BUREAU OF MINES (1)

Direct Combustion or Low Btu Gasification for process steam applications) will not have a significant impact on total quantity of oil consumed in the region since 1974 industrial consumption of oil was only 0.2 quad.

Conclusions

Since New England uses a relatively small amount of energy resources, it might be argued that it is preferable for the region to continue importing oil rather than switching to alternative fuel sources. But, since most of the energy consumed is in the form of petroleum, 2.3 quads, some alternatives should be considered.

Imports of coal liquids and oil shale liquids derived from Coal Liquefaction and Oil Shale technologies could potentially replace 1.7 quads of oil used in the transportation and residential/commercial sectors. Direct Combustion and Advanced Power Systems potentially could eliminate 0.5 quad of oil consumption in the electric utility sector.

Oil and Gas Extraction Technologies applied in other regions could supply the transportation and R/C sector with domestic instead of imported oil. The impact of these technologies within the region is dependent upon presently unknown offshore reserves.

2. Middle Atlantic Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the Middle Atlantic (MA) region is given in Table 20. The MA region is the nation's largest consumer of oil. Also, it is the third largest consumer of scarce fossil fuels, as measured by the Consumption Index value, 122, shown in Table 21. The Residential/Commercial sector consumes far more oil than any other regional R/C sector (1.7 quads). The Electric Utility sector consumes almost 1.0 quad of oil, second only to the South Atlantic utility sector in oil consumption. MA regional petroleum reserves are relatively insignificant. Hence, the MA region has become the largest oil importing region in the nation. The MA region is also a consumer of 2.1 quads of coal. The region's Dependence Index value (96) is much lower than it would be without coal utilization.

TABLE 21
REGIONAL ENERGY MATRIX

MIDDLE ATLANTIC

INDEX	TOTAL	SECTOR	C	O	G	N	H
U CONSUMPTION	122		0	93	28	1	0
			CONSUMPTION (10 ¹⁵ BTU)				
		TRANS 165	0	2.4	0	-	-
		INDUS 62	1.0	.4	.5	-	-
		R/C 188	0	1.7	1.1	-	-
		ELEC 75	1.0	1.0	0	.2	.3
D DEPENDENCE	96		0	73	22	1	0
			DEPENDENCE (PERCENT)				
		TOTAL	22	55	17	2	4
		TRANS 132	0	99	1	-	-
		INDUS 63	52	21	27	-	-
		R/C 131	0	61	39	-	-
		ELEC 55	40	37	2	8	13
P POPULATION INDUCED CONSUMPTION	147		0	118	28	1	0
			DISTRIBUTION (PERCENT)				
			9	69	17	2	3
I INDUSTRY INDUCED CONSUMPTION	74		1	43	29	1	0
			DISTRIBUTION (PERCENT)				
			48	26	18	3	5

Regional Resources and Applicable Technologies

Oil and natural gas reserves in western New York and Pennsylvania are insignificant compared with regional consumption of these resources. An assessment of potential oil and gas reserves off the New Jersey coast is not yet available to determine if Oil and Gas Extraction technologies have potential in the region. For purposes of this analysis, it is assumed that these technologies are applicable, but will not make a significant contribution to MA oil and gas supplies in the near future.

The MA region contains 7 percent of the U.S. coal reserves and supplies 15 percent of the coal produced nationally. This coal is found in Pennsylvania which ranks first among the 50 states in the production of anthracite and third in the production of bituminous coals. The MA region consumes almost as much coal as Pennsylvania produces. If coal conversion technologies are to be introduced within the region, more mines must be opened and production increased.

The three states in the region have a dense and well-developed system for transporting various forms of energy. Oil and gas pipelines connect all of the major cities and industrial centers. Approximately 81 million tons of coal were handled by regional transportation systems in 1974. Railways are extensive, although some have been allowed to deteriorate. In many places spur line tracks, rolling stock and terminal facilities are in disrepair or have been abandoned. Port and shipping facilities for handling oil are excellent, particularly in New Jersey, but coal handling facilities would have to be improved if there were to be a significant regional shift from the use of oil and natural gas to coal.

Assuming that coal production can be increased and coal handling facilities improved, Coal Gasification to High and Low Btu gas, Direct Combustion, Coal Liquefaction, and Advanced Power systems are considered applicable within the MA region (Table 22). Since there is no high grade shale oil in the region, these technologies are not applicable.

Consuming Sectors

A. Residential/Commercial

The extensive use of oil and gas by the R/C sector is reflected in the very high Consumption Index value of 188 for this sector. The R/C sector

TABLE 22. MIDDLE ATLANTIC REGION
FOSSIL ENERGY TECHNOLOGY MATRIX

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS							APPLICATION INDEX
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL			REMARKS		
														AIR	WATER	SOLID WASTE			
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SNG 250 x 10 ⁶ CuFt/day 91,250 x 10 ⁶ BTU/year 1,000 BTU/CuFt 91.25 x 10 ¹² BTU/year OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY NAPHTHA - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 43 TONS/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF COKING COALS WHICH AGGLOMERATE IN GASIFIERS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	●	
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CuFt/day 521,714 x 10 ⁶ BTU/year 175 BTU/CuFt 91.3 x 10 ¹² BTU/year OTHER PRODUCTS NONE	11.8 x 10 ³ TONS/DAY 4488 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5278 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 26 SOx 30-40 HC 3 CO 2	BOD 30PPM COD 25PPM TDS 250PPM	865 TONS/DAY (9,000 TONS/DAY OF SPENT DOLOMITE IF USED)	• UTILIZATION OF COKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS OF SCALE-UP. • HIGH CAPITAL INVESTMENT.	●	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (39 MW) 72x10 ³ KWHR/DAY 263x10 ⁶ KWHR/DAY 3,412 BTU/KWHR 0.9 x 10 ¹² BTU/year OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES YR/10 ¹² BTU	UNKNOWN	\$ 20x10 ⁶ to \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 BTU/KWHR	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TON/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	17 TONS/DAY	• FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • SORBENT REGENERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.D. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	●	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWHR/DAY 5,563 x 10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 19.2x10 ¹² BTU/YR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,191 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	43.8x10 ⁶ KWHR/YR	6.1 MGD	DOLOMITE - 485 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE YR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGES LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.	●	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ BTU/BARREL 207.0 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,261x10 ⁶ KWHR/YR	3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT POLYBENZENE 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 63%	1990 - 2000	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	HOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.	●	
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL .49 x 10 ³ BARRELS/DAY 178 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ BTU/BARREL 1 x 10 ¹² BTU/YEAR OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - YR/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 30% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(TONS/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. • RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAR SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	●	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ⁶ BTU/BARREL 211.7 x 10 ¹² BTU/YEAR OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	132x10 ³ TONS/DAY 48,180x10 ³ TONS/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 67%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	AMINES 190PPM CARBONATES 500PPM CHLORIDES 330PPM CHROMATES 130PPM CYANIDES 50PPM ORGANIC ACIDS 1000PPM PHENOLS 60PPM	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A	

REGIONAL RESOURCES AND CHARACTERISTICS	REGIONAL CONSUMPTION (1974)	RESERVES - 31,000,600 x 10 ³ TONS			AUGUSTON - 26.4 x 10 ⁶ COKING PROPERTIES PRODUCTION - 87,079 x 10 ³ TONS			RESERVES 61,312 x 10 ³ BARRELS PRODUCTION 4,374 x 10 ³ BARRELS			RESERVES 1,657,691 x 10 ⁶ Cu.Ft. PRODUCTION 87,627 x 10 ⁶ Cu.Ft.			DISTRIBUTED 253,292 x 10 ⁶ KWHR	DEPLETION RATE 1.6% CONSUMPTION (M.G.D.) 1,681	DOMESTIC 700 MANUFACTURING 511 MINERALS 71 STEAM ELECTRIC 143 OTHER 255	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE 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uses more oil (1.7 quads) than any other R/C sector in the country. Natural gas consumption in this sector (1.1 quads) is the second largest nationally. While Pennsylvanians use equal quantities of oil and gas for home heating, the R/C sectors in New York and New Jersey are about twice as dependent on oil as they are on natural gas.

If the economics are favorable and technical constraints can be resolved, the introduction of coal liquefaction plants into the coal producing areas of Pennsylvania could potentially replace oil consumption by the R/C sector with liquids from coal. Imports of liquids from oil shale retorting facilities in other regions through existing pipelines could have the same impact.

Synthetic natural gas, derived from High Btu Gasification technologies, also based in Pennsylvania, could alleviate the region's dependence on imports of natural gas from the West South Central Region. With the introduction of these technologies, crises of the magnitude of that which occurred during the winter of 1976-77 could be avoided.

The high R/C Consumption Index value, 188, is reflected in a high value for the Population-Induced Consumption Index, 147. Application of the advanced fossil technologies in the MA region, discussed above, could reduce both values.

B. Electric Utility

The electric utility sector of the MA region consumes almost as much oil (1 quad) as the nation's greatest oil consuming electric utility sector (South Atlantic region). While Pennsylvania's utilities are only 14 percent dependent on oil (76 percent dependent on coal), New York and New Jersey utilities, respectively, are 47 percent and 68 percent dependent on oil.

Direct Combustion of coal in atmospheric fluidized beds for power generation could be used with the high sulfur coal found in Pennsylvania and shipped to New York and New Jersey. The combustion of coal-oil slurries in the utility sector could also help to reduce dependence on oil. This technology is particularly applicable to New York and New Jersey, especially in plants retrofitted to burn oil. Direct Combustion technologies could significantly reduce the oil burned for power generation. More efficient Advanced Power Systems could have a similar effect.

C. Industrial

The MA region's industrial sector is the third largest regional industrial energy consumer in the country. This is due primarily to high industrial energy usage in Pennsylvania. Just under one-third of the total energy consumed in Pennsylvania is industrial, whereas the industrial sectors of New Jersey and New York account for less than 11 percent of the energy use in each state.

Over half the energy consumed by industry is in the form of coal. Only 0.5 quad of natural gas and 0.4 quad of oil are consumed by industry. Low Btu Gasification technologies could supply approximately 0.6 quad of energy to the Industrial sector. Intermediate Btu gas from coal could be used for chemical feedstocks.

Conclusions

Coal Liquefaction potentially could eliminate 4.1 quads of foreign oil imports used in the R/C and transportation sectors.

Liquids from Oil Shale imported from outside the region could have the same potential impact.

Direct Combustion technologies could supplant the use of 1.4 quads of oil and gas in the industrial and electric utility sectors. More efficient Advanced Power Systems could be used to reduce the electric utilities' use of oil.

R/C use of natural gas could potentially be replaced by synthetic gas from High Btu Gasification technologies, a potential impact of 1.1 quads. Low Btu Gasification could be used in industry, replacing 0.6 quad of oil and gas use. The products of Oil and Gas Extraction techniques, applied in other regions, could be shipped into the MA region. The impact of Oil and Gas Extraction technologies within the region can only be considered small until the extent of the reserves off the New Jersey coast is determined.

3. South Atlantic Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the South Atlantic (SA) region is given in Table 23. The SA region is the second largest consumer and importer of oil, most of which comes to the region in the form of costly foreign

TABLE 23. SOUTH ATLANTIC REGION
SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																		NET IMPORTS (FOREIGN & DOMESTIC)				
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁹ Cu.Ft.	URANIUM U ₃ O ₈ 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁹ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP
DELAWARE	0	0	0	0	0	1	0	FOSSIL 15	0	0	0	0	0	0	COAL	—	.6	0	18.3	.3	19.2	—	3	0	95	2	100	—	2	0	87	4	10	19.2	150.5	21.2	190.9
								NUCLEAR 0	0	0	0	0	0	0	OIL	48.1	18.2	27.8	50.0	6.4	150.5	32	12	19	33	4	100	100	46	58	72	96	79				
								HYDRO 0	0	0	0	0	0	0	NG	0	9.5	10.8	.9	—	21.2	0	45	51	4	—	100	0	24	22	1	—	11				
	0	0	0	0	0			HYDRO 0	0	0	0	0	0	0	ELECT	(0)	(11.0)	(9.6)	—	—	(20.6)	0	54	46	—	—	100	0	28	20	—	—	—				
FLORIDA	0	302,709	308,866	0	0	1	1	FOSSIL 91	0	36,351	38,137	251	7,877	0	COAL	—	0	0	143.3	0	143.3	—	0	0	100	0	100	—	0	0	18	0	8	143.3	1,079.7	253.9	1,476.7
								NUCLEAR 1	0	0	0	0	0	0	OIL	686.7	73.2	105.0	422.5	3.1	1,290.5	53	6	8	33	0	100	100	33	30	52	100	71				
								HYDRO 2	0	210.8	41.8	2.7	84.0	339.3	NG	3.1	97.0	38.1	157.3	—	295.5	1	33	13	53	—	100	0	44	11	20	—	16				
	0	1,755.7	338.8	0	0			HYDRO 2	0	0	0	0	0	0	ELECT	(0)	(52.4)	(201.6)	—	—	(254.0)	0	21	79	—	—	100	—	0	24	51	—	—	—			
GEORGIA	500	8	0	0	0	2	0	FOSSIL 23	0	0	0	3,605	44	0	COAL	—	7.6	1.1	248.3	0	255.0	—	3	0	97	0	100	—	3	0	65	0	20	255.0	643.2	342.8	1,241.0
								NUCLEAR 0	0	0	0	0	0	0	OIL	454.1	59.7	74.0	49.8	5.6	643.2	71	9	11	8	1	100	99	20	25	13	100	50				
								HYDRO 26	0	0	0	36.1	.5	36.6	NG	5.0	170.4	123.1	44.3	—	342.8	1	50	36	13	—	100	1	58	42	12	—	27				
	12.9	0	0	0	0			HYDRO 26	0	0	0	0	0	0	ELECT	(0)	(54.1)	(98.7)	—	—	(152.8)	0	35	65	—	—	100	—	0	19	33	—	—	—			
MARYLAND (AND D.C.)	1,048,200	0	0	0	0	1	0	FOSSIL 31	2,337	0	133	1,691	0	0	COAL	—	121.5	1.5	111.8	1.4	236.2	—	51	1	47	1	100	—	43	0	33	45	19	176.7	776.9	207.1	1,160.8
								NUCLEAR 0	0	0	0	0	0	0	OIL	325.6	50.4	198.0	201.2	1.7	776.9	42	7	25	26	0	100	99	10	49	59	55	63				
								HYDRO 3	59.5	0	.1	14.2	0	73.8	NG	1.8	62.7	128.7	14.1	—	207.3	1	30	62	7	—	100	1	22	32	4	—	17				
	26,666.2	0	0	0	0			HYDRO 3	0	0	0	0	0	0	ELECT	(.8)	(46.7)	(75.1)	—	—	(122.6)	1	38	61	—	—	100	—	0	17	19	—	—	—			
NORTH CAROLINA	31,700	0	0	0	0	0	0	FOSSIL 34	0	0	0	5,887	0	0	COAL	—	36.2	7.2	459.1	0	502.5	—	7	1	91	0	100	—	14	2	82	0	37	502.5	657.5	145.8	1,305.8
								NUCLEAR 0	0	0	0	0	0	0	OIL	413.2	65.7	136.8	34.9	6.9	657.5	63	10	21	5	1	100	99	24	45	6	100	48				
								HYDRO 42	0	0	0	66.0	0	66.0	NG	4.6	91.3	48.8	1.1	—	145.8	3	63	33	1	—	100	1	34	16	0	—	10				
	835.6	0	0	0	0			HYDRO 42	0	0	0	0	0	0	ELECT	(0)	(75.6)	(111.7)	—	—	(187.3)	0	40	60	—	—	100	0	28	37	—	—	—				
SOUTH CAROLINA	0	0	0	0	0	0	0	FOSSIL 37	0	0	0	3,413	11,057	0	COAL	—	33.6	4.7	155.7	0	194.0	—	17	3	80	0	100	—	17	3	41	0	23	194.0	335.1	140.0	669.1
								NUCLEAR 2	0	0	0	0	0	0	OIL	212.4	31.8	51.2	38.1	1.6	335.1	63	10	15	11	1	100	99	16	35	10	100	40				
								HYDRO 25	0	0	0	44.2	117.9	162.1	NG	2.2	79.8	35.9	22.1	—	140.0	2	67	25	16	—	100	1	40	24	6	—	17				
	0	0	0	0	0			HYDRO 25	0	0	0	0	0	0	ELECT	(0)	(53.1)	(56.6)	—	—	(109.7)	0	48	52	—	—	100	—	0	27	38	—	—	—			
VIRGINIA	3,649,700	0	44,707	0	0	1	0	FOSSIL 28	34,326	3	7,096	1,045	5,953	0	COAL	—	61.3	13.3	107.8	.2	182.6	—	34	7	59	0	100	—	27	4	30	7	15	-722.2	810.6	144.2	232.6
								NUCLEAR 1	0	0	0	0	0	0	OIL	451.0	71.6	111.5	174.0	2.5	810.6	56	9	14	21	0	100	99	32	35	48	93	66				
								HYDRO 23	904.8	0.0	7.8	11.2	63.5	987.3	NG	4.3	57.6	85.2	4.9	—	152.0	3	38	56	3	—	100	1	26	27	1	—	13				
	96,074.1	0	49.0	0	0			HYDRO 23	0	0	0	0	0	0	ELECT	(0)	(34.9)	(104.6)	—	—	(139.5)	0	25	75	—	—	100	0	15	33	—	—	—				
WEST VIRGINIA	39,589,800	32,210	2,265,581	0	0	3	4	FOSSIL 14	102,461	2,005	202,306	477	0	0	COAL	—	252.7	8.8	551.9	0	813.4	—	31	1	60	0	100	—	57	7	98	0	65	-1932.6	201.5	-12.9	-1,744.0
								NUCLEAR 0	0	0	0	0	0	0	OIL	120.7	74.2	13.7	7.9	.5	217.0	56	34	6	4	0	100	88	15	10	1	100	17				
								HYDRO 8	2,746.0	15.5	221.9	4.4	0	2,987.8	NG	16.0	112.6	80.0	.4	—	209.0	8	54	36	0	—	100	12	24	62	0	—	—	17			
	1,061,006.6	186.8	2,485.3	0	0			HYDRO 8	0	0	0	0	0	0	ELECT	(0)	(37.7)	(27.2)	—	—	(64.9)	0	58	42	—	—	100	—	0	8	21	—	—	—			
SOUTH ATLANTIC	44,319,900	334,919	2,619,154	0	0	9	5	FOSSIL 273	139,124	39,019	247,672	17,369	24,931	0	COAL	—	513.5	36.6	1,794.2	1.9	2,346.2	—	22	2	76	0	100	—	26	2	52	6	28	-1364.1	4,655.0	1,242.0	4,532.9
								NUCLEAR 4	0	0	0	0	0	0	OIL	2,711.8	444.8	718.0	978.4	28.3	4,881.3	55	9	15	10	1	100	99	22	36	28	94	53				
								HYDRO 129	3,710.3	226.3	271.6	178.8	265.9	4,652.9	NG	37.0	680.9	550.6	245.1	—	1,513.6	3	45	36	16	—	100	1	34	28	7	—	16				
	1,184,595.4	1,942.5	2,873.1	0	0			HYDRO 129	0	0	0	0	0	0	ELECT	(0.8)	(365.5)	(6																			

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

imports. Total regional oil consumption is 4.9 quads, of which 56 percent is consumed in the transportation sector. The electric utility sector in the SA region uses more petroleum (1 quad) than the electric utility sector in any other region. Both the Residential/Commercial and Industrial sectors use relatively large quantities of both oil and gas. Due to the scarcity of oil and natural gas resources within the SA region, it is forced to import almost all of the oil and gas utilized.

Although the region is a large consumer of oil, it also is the second largest regional consumer of coal. These factors are reflected in the high Consumption Index value, 112, and the low Dependence Index value, 93 (Table 24). The high Population-Induced Consumption Index value, 124, reflects the extensive use of oil and gas in the R/C and electric utility sectors, and the oil used in the transportation sector.

Regional Resources and Applicable Technologies

Although the SA region has only 12 percent of the nation's known coal reserves, considerably less than the East North Central or Mountain states, it produces 25 percent of the coal mined in the country. Nearly 90 percent of the coal reserves in the region are located in West Virginia. West Virginia also accounts for 74 percent of regional coal production or 102 million tons. Virginia and Maryland are the only other coal producing states in the region. While there are some problems associated with the railroads serving the coal fields of West Virginia, improvements in existing lines, rolling stock and facilities could allow for an even greater rate of coal production within the region. No serious regional constraints exist to the introduction of coal conversion technologies (Table 25).

The SA region produces relatively small amounts of oil and gas (0.5 quad total). Enhanced Oil and Gas Recovery technologies can therefore have only a minor effect. However, if substantial offshore gas and oil reserves are found, offshore technologies could be applied. Pipeline systems throughout the region are well developed.

There are no high grade shale oil deposits in the SA region.

TABLE 24
REGIONAL ENERGY MATRIX

SOUTH ATLANTIC

INDEX	TOTAL	SECTOR	C	O	G	N	H
U CONSUMPTION	112		1	85	25	1	0
			CONSUMPTION (10 ¹⁵ BTU)				
		TRANS 191	0	2.7	0	-	-
		INDUS 78	.5	.4	.7	-	-
		R/C 87	0	.7	.6	-	-
		ELEC 90	1.8	1.0	.2	.3	.2
D DEPENDENCE	93		1	70	21	1	0
			DEPENDENCE (PERCENT)				
		TOTAL	26	53	16	3	2
		TRANS 132	0	99	1	-	-
		INDUS 90	31	27	42	-	-
		R/C 127	3	55	42	-	-
		ELEC 50	52	28	7	8	5
P POPULATION INDUCED CONSUMPTION	124		1	104	18	1	0
			DISTRIBUTION (PERCENT)				
			19	65	11	3	2
I INDUSTRY INDUCED CONSUMPTION	87		1	44	41	1	0
			DISTRIBUTION (PERCENT)				
			40	28	27	3	2

**TABLE 25. SOUTH ATLANTIC REGION
FOSSIL ENERGY TECHNOLOGY MATRIX**

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS							APPLICATION INDEX
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL			REMARKS		
														AIR	WATER	SOLID WASTE			
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SHG 250 x 10 ⁶ CUBIC FEET/DAY 91,250 x 10 ⁶ BTU/YEAR 1,000 BTU/CUBIC FOOT 91.25 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ⁴ TONS/DAY WASTEWATER - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 43 TONS/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF CAKING COALS WHICH AGGLOMERATE IN GASIFIERS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	●	
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CUBIC FEET/DAY 521,719 x 10 ⁶ BTU/YEAR 175 BTU/CUBIC FOOT 91.3 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6488 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5279 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 2% SOx 30-40 HC 3 CO 2	BOD 30PPM COD 25PPM TDS 250PPM	865 TONS/DAY (4,000 TONS/DAY OF SPENT DOLOMITE IF USED)	• UTILIZATION OF CAKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS OF SCALE-UP. • HIGH CAPITAL INVESTMENT.	●	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (39 MW) 720x10 ³ KWHR/DAY 263x10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 0.9 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.78 ACRES YR/10 ¹² BTU	UNKNOWN	\$ 20x10 ⁶ to \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 BTU/KWHR	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TON/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	17 TONS/DAY	• FEED ASH DISPOSAL AND WASTE GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • SORBENT REGENERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.B. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	●	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (335 MW) 15,240x10 ³ KWHR/DAY 5,563 x 10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 19.2x10 ¹² BTU/YR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	43.8x10 ⁶ KWHR/YR	6.1 MGD	DOLOMITE - 485 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE YR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGER LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.	●	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ BTU/BARREL 207.0 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,261x10 ⁶ KWHR/YR	3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT POLYBODENUM 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 63%	1990 - 2000	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	BOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.	●	
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL .49 x 10 ³ BARRELS/DAY 178 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ BTU/BARREL 1 x 10 ¹² BTU/YEAR OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - YR/10 ¹² BTU	UNKNOWN	\$ 0.5x10 ⁶ to \$10x10 ⁶ YR FOR AN OFFSHORE WELL (1973 COSTS)	ONSHORE 30% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(TONS/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 310 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED ON ENHANCED OIL RECOVERY. • RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAP SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND WASTE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	◐	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ BTU/BARREL 211.7 x 10 ¹² BTU/YEAR OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,261x10 ⁶ KWHR/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 67%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	AMINES 1900PPM CARBONATES 520PPM CHLORIDES 330PPM CHROMIUMS 1500PPM CYANIDES 50PPM ORGANIC ACIDS 1000PPM PHENOLS 60PPM	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND DIFFICULT. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A	

[illegible]

Consuming Sectors

A. Electric Utility

Even though the SA electric utility sector is 52 percent dependent on coal, this sector also consumes about 1 quad of oil. Individual states in the SA region vary considerably in their use of these two fuels in this sector. For example, the EU sector in West Virginia is 98 percent dependent on coal. In Delaware, Maryland, and Florida EU dependence on oil exceeds 50 percent.

Approximately 37 percent of regional coal reserves has a sulfur content of less than 1 percent. If this coal can be extracted, it could be used in conjunction with Direct Combustion technologies in new power plants or combined with oil in coal-oil slurries, thereby reducing oil consumption by electrical utilities. The introduction of Direct Combustion technologies potentially could result in replacement of 1 quad of oil by more abundant coal.

Advanced Power Systems could be an equally effective means of reducing oil use in power generation. These technologies also could replace the 0.2 quad of natural gas currently consumed by the Electric Utility sector.

B. Residential/Commercial

The R/C sector is highly dependent on oil and gas, as reflected by this sector's high Dependence Index value of 127. This sector could make use of indigenous coal liquefaction and gasification plants as an alternative to importing oil and gas. Coal Liquefaction and High Btu Gasification plants located in coal producing states within the region could ship their products to consumers in other states of the SA region through existing pipeline networks and eliminate the use of 0.7 quad of oil and 0.6 quad of natural gas.

C. Industrial

Low Btu Gasification could be applied within the SA industrial sector to generate process heat and steam. The chemical industry, particularly in West Virginia, Virginia, Delaware and Maryland could use intermediate Btu gas as a feedstock. While low and intermediate Btu gas could not be used to replace all the natural gas and oil used in industry (technology

substitution factors are given in Chapter II, Table 12), they could replace a large percentage of industrial oil and gas (0.8 quad).

Direct Combustion technologies could provide an alternative to 0.6 quad of oil and gas consumed by industry.

Conclusions

Assuming that technical and economic constraints can be resolved, Coal Liquefaction have the most significant effect on reducing the regional consumption of critical fuels. The products of Oil Shale technology, implemented in other regions, could be shipped to the SA region with similar effects. The introduction of either or both of these technologies could provide the 3.4 quads of energy needed to fuel both the transportation sector and the oil consumed by the R/C sector.

Direct Combustion and/or Advanced Power technologies could provide substitutes for approximately 1.2 quads of oil and gas now used for power generation by the electric utilities. Direct Combustion of coal also could be used to replace about 0.6 quad of oil and gas consumed by industry.

The potential market for High Btu Gasification products is approximately 0.6 quad within the Residential/Commercial sector. Low Btu gas can be used by industry as a substitute for natural gas and petroleum in process heat and steam applications. A total potential market of 0.8 quad exists within industry for Low Btu Gasification technology. The probable effects of Oil and Gas Extraction Technologies applied in the SA region appear to be relatively insignificant compared to the other technologies, unless offshore oil and gas reserves are proven to be substantial.

4. East North Central Region

Review of Significant Energy Characteristics

The East North Central (ENC) region is the nation's largest energy consumer. The ENC region has been used as an example in Chapter II to explain how pertinent supply/demand data are processed to develop the various Energy Indices and to assess the potential impact of advanced fossil technologies on regional energy posture. For convenience, some of the Figures from Chapter II will be reproduced below.

The Supply/Demand profile for the ENC region is given in Table 3. This region is the nation's largest regional consumer of coal (4.4 quads), the second largest consumer of natural gas (4.2 quads) the the third largest consumer of oil (4.8 quads). Consequently, the value of the Consumption Index, 157, shown in Table 9 is correspondingly large, although it is not so high as the Consumption Index for the West South Central region, 198. This is due to the fact that about one-third of the energy requirements of the ENC region are met by using relatively abundant coal. This is reflected in a Dependence Index value of 87, which is below the national average.

Despite heavy usage of coal, there is still a large market for alternatives to gas and oil use in the ENC region. For example, the industrial sector consumes 1.7 quads of natural gas per year and the R/C sector utilizes 2.3 quads of gas and 1.2 quads of oil annually.

Regional Resources and Applicable Technologies

About 20 percent of the coal produced in the nation is mined in the ENC region. The region has the second largest reserves of coal in the country and is the third largest coal producing region. Almost all of the coal is located in Illinois, Indiana and Ohio.

The East North Central region has an excellent coal transportation network. The railroad network, particularly in Ohio, Indiana, and Illinois, provides direct linkages between urban and industrial centers and the coal mines. The region borders on the Great Lakes and is linked to the Atlantic Ocean via the St. Lawrence Seaway to the north. It is bounded by the Mississippi River to the west and the Ohio River to the south. Its waterway and marine facilities are among the best in the country for transporting all forms of fossil energy. The dense network of oil and gas pipelines within the region is sufficient to handle future products from coal conversion technologies.

The Fossil Energy Technology Matrix for the ENC region is presented in Table 11. Despite abundant ENC coal reserves, the region currently imports over 30 percent of its regional needs. Illinois is the only state in the region that produces more coal than it consumes. Coal conversion technologies such as Coal Liquefaction, High and Low Btu Gasification, Direct

Combustion and Advanced Power Systems can be introduced if regional production and/or coal imports are increased.

Enhanced Recovery techniques are expected to have a minimal impact on the oil supply because the ENC region does not have abundant reserves of oil and produces only 0.3 quad of oil a year.

Consuming Sectors

A. Residential/Commercial

The R/C Sector in the ENC region consumes more total energy than any other regional R/C sector. Approximately 30 percent of the natural gas and 18 percent of the oil consumed by the national R/C sector is consumed in the ENC region. The ENC region has the largest R/C sector Consumption Index value in the nation, 236.

The introduction of an extensive network of High Btu Gasification facilities within the coal-producing states potentially could replace 2.3 quads of natural gas. Coal Liquefaction technologies could save 1.2 quads of oil consumed by the R/C sector if technical and economic constraints can be overcome.

B. Industrial

The ENC Industrial sector uses over 40 percent of the coal consumed by the national industry. It is also the second largest regional industrial consumer of natural gas (1.7 quads). Gasification of coal to produce a low Btu gas for generating industrial process heat and steam would have a maximum potential impact of 1.6 quads. Coal gasification to intermediate Btu gas for chemical feedstocks could again be applied in the region. (This was done in the past prior to availability of cheap natural gas.)

C. Electric Utility

More electricity is produced in the East North Central region than in any other region. However, the electric utilities are already 80 percent dependent on coal, the less critical energy resource. This is reflected in the extremely low sector Consumption Index value, 34, and sector Dependence Index value, 18. Only the East South Central region consumes less oil and gas in the electric utility sector than the ENC region.

Direct Combustion technologies could be used in new plants or to retrofit existing facilities to reduce current usage of 0.4 quad of oil and gas. Advanced Power Systems for generating electricity could have a similar impact.

Conclusions

Oil consumption by the R/C and Transportation sectors in the ENC region, a total of 4.1 quads, potentially could be replaced by liquids from Coal Liquefaction technologies located within the region. Essentially the same impact could be produced by importing synthetic liquid products derived from Oil Shale plants located in other regions.

Natural gas consumed by the R/C sector (2.3 quads) could be replaced with synthetic gas from High Btu Gasification plants. Coal for the gasification process could come from within the region if production is increased.

Low Btu gas may be used by the Industrial sector to potentially reduce gas and oil consumption by 1.6 quads. Direct Combustion could have a potential impact of 1.4 quads on oil and gas consumption by the Industrial and Electric Utility sectors.

The impact of Secondary and Tertiary Oil and Gas Recovery techniques within the region is not expected to be large due to the small reserves of oil and gas.

5. East South Central Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the East South Central (ESC) region is given in Table 26. Only the Mountain States and New England consume less energy than this region. The ESC region has both a low Consumption Index value, 46, and the lowest Dependence Index value, 77, (Table 27). The region is 35 percent dependent on coal; hence the low index values. While the regional industrial and residential/commercial sectors are both relatively dependent on natural gas, the total amount of gas consumed by these two sectors is only 0.9 quad.

TABLE 26. EAST SOUTH CENTRAL REGION
SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION					CONSUMPTION																				NET IMPORTS (FOREIGN & DOMESTIC)			
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM U ₃ O ₈ 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP
ALABAMA	2,981,800	68,718	507,370	0	0	4	2	FOSSIL 16	19,823	13,323	27,865	10,344	6,289		COAL	—	231.7	.7	368.1	0	600.5	—	39	0	61	0	100%	—	44	0	68	0	40	90.3	357.3	257.3	704.9
								NUCLEAR 1								OIL	323.3	31.2	69.9	4.5	5.7	434.6	75	7	16	1	1	100%	94	6	30	1	100	29			
								HYDRO 19	510.2	77.3	30.6	94.4	67.0	779.5	NG	19.7	170.6	92.4	5.2	—	287.9	7	59	32	2	—	100%	6	33	40	1	—	20				
76,751.5	398.6	556.5	0	0											ELECT*	(0)	(88.1)	(71.2)	—	—	(159.3)	0	55	45	—	—	100%	0	17	30	—	—		15%	82%	89%	47%
														HYDRO	—	—	—	94.4	—	94.4	—	—	—	100	—	100%	—	—	—	18	—	6					
														NUCLEAR	—	—	—	67.0	—	67.0	—	—	—	100	—	100%	—	—	—	12	—	5					
														TOTAL	343.0	433.5	163.0	539.2	5.7	1,484.4	23	29	11	36	0	100%	100%	100%	100%	100%	100%						
KENTUCKY	25,540,600	36,572	844,002	0	0	4	2	FOSSIL 26	137,198	7,837	71,876	3,398	0		COAL	—	88.3	6.8	462.9	0	558.0	—	16	1	83	0	100%	—	30	3	92	0	48	-2935.1	298.3	160.8	-2,476.0
								NUCLEAR 0								OIL	257.3	27.0	56.3	1.7	1.5	343.8	75	8	16	1	0	100%	90	9	22	0	100	29			
								HYDRO 6	3,493.1	45.5	78.8	31.9	0	3,649.3	NG	30.0	83.1	120.9	5.6	—	239.6	13	35	50	2	—	100%	10	28	48	1	—	20				
	633,713.4	212.1	925.9	0	0										ELECT*	(0)	(95.7)	(68.3)	—	—	(164.0)	0	58	42	—	—	100%	0	33	27	—	—		-526%	87%	67%	-211%
														HYDRO	—	—	—	31.9	—	31.9	—	—	—	100	—	100%	—	—	—	7	—	3					
														NUCLEAR	—	—	—	0	—	0	—	—	—	0	—	100%	—	—	—	0	—	0					
														TOTAL	287.3	198.4	184.0	502.1	1.5	1,173.3	24	17	16	43	0	100%	100%	100%	100%	100%	100%						
MISSISSIPPI	0	261,408	1,079,420	0	0	5	8	FOSSIL 26	0	50,779	78,787	0	0		COAL	—	1.2	0	35.4	0	36.6	—	3	0	97	0	100%	—	1	0	25	0	6	36.6	49.2	204.0	289.8
								NUCLEAR 0								DIL	191.0	26.6	61.3	61.6	3.2	343.7	55	8	18	1	100%	79	14	38	44	100	51				
								HYDRO 0	0	294.5	86.4	0	0	380.9	NG	51.4	139.6	55.5	43.9	—	290.4	18	48	19	15	—	100%	21	72	35	31	—	43				
	0	1,516.2	1,184.1	0	0										ELECT*	(0)	(25.8)	(44.0)	—	—	(69.8)	0	37	63	—	—	100%	0	13	27	—	—		100%	14%	70%	43%
														HYDRO	—	—	—	0	—	0	—	—	—	0	—	100%	—	—	—	0	—	0					
														NUCLEAR	—	—	—	0	—	0	—	—	—	0	—	100%	—	—	—	0	—	0					
														TOTAL	242.4	167.4	116.8	140.9	3.2	670.7	36	25	17	21	1	100%	100%	100%	100%	100%	100%						
TENNESSEE	986,700	0	0	0	0	1	0	FOSSIL 11	7,540	769	17	11,767	0		COAL	—	58.5	6.4	354.6	0	419.5	—	14	1	85	0	100%	—	15	3	77	0	34	222.0	437.1	268.5	927.5
								NUCLEAR 0								OIL	353.0	22.3	62.7	2.3	1.3	441.6	80	5	14	1	0	100%	94	6	25	1	100	36			
								HYDRO 28	197.5	4.5	0.0	102.6	0	304.6	NG	24.5	153.8	90.1	0	—	268.4	9	5	34	0	—	100%	6	40	35	0	—	22				
	25,851.5	0	0	0	0										ELECT*	(0)	(149.1)	(95.4)	—	—	(244.5)	0	61	39	—	—	100%	0	39	37	—	—		53%	99%	100%	75%
														HYDRO	—	—	—	102.6	—	102.6	—	—	—	100	—	100%	—	—	—	22	—	8					
														NUCLEAR	—	—	—	0	—	0	—	—	—	0	—	100%	—	—	—	0	—	0					
														TOTAL	377.5	234.6	159.2	459.5	1.3	1,232.1	31	19	13	37	0	100%	100%	100%	100%	100%	100%						
EAST SOUTH CENTRAL	29,509,100	366,698	2,430,792	0	0	14	12	FOSSIL 79	164,561	72,708	178,545	25,509	6,289		COAL	0	379.7	13.9	1,221.0	0	1,614.6	0	24	1	75	0	100%	0	27	1	75	0	35	-2,585.2	1,141.9	890.5	-553.8
								NUCLEAR 1								OIL	1,124.6	107.1	250.2	70.1	11.7	1,563.7	72	7	16	4	1	100%	90	8	28	4	100	34			
								HYDRO 53	4,200.8	421.8	195.9	228.8	67.0	5,114.3	NG	125.6	547.2	358.9	54.7	0	1,086.4	12	50	33	5	—	100%	10	39	40	3	—	24				
	736,316.4	2,126.9	2,666.5	0	0										ELECT*	(0)	(358.7)	(278.8)	—	—	(637.5)	0	56	44	—	—	100%	0	26	31	—	—		-160%	73%	82%	-12%
														HYDRO	—	—	—	228.8	—	228.8	—	—	—	100	—	100%	—	—	—	14	—	5					
														NUCLEAR	—	—	—	67.0	—	67.0	—	—	—	100	—	100%	—	—	—	4	—	2					
														TOTAL	1,250.2	1,034.0	623.0	1,641.6	11.7	4,560.5	27	23	14	36	0	100%	100%	100%	100%	100%	100%						

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

TABLE 27
REGIONAL ENERGY MATRIX

EAST SOUTH CENTRAL

<u>INDEX</u>	<u>TOTAL</u>	<u>SECTOR</u>	<u>C</u>	<u>O</u>	<u>G</u>	<u>N</u>	<u>H</u>
U CONSUMPTION	46		1	27	18	0	0
			<u>CONSUMPTION (10¹⁵ BTU)</u>				
		TRANS 87	0	1.1	.1	-	-
		INDUS 45	.4	.1	.5	-	-
		R/C 42	0	.3	.4	-	-
		ELEC 11	1.2	0	0	.1	.2
D DEPENDENCE	77		1	45	31	0	0
			<u>DEPENDENCE (PERCENT)</u>				
		TOTAL	35	34	24	2	5
		TRANS 132	0	90	10	-	-
		INDUS 83	37	10	53	-	-
		R/C 127	2	40	58	-	-
		ELEC 12	75	4	3	4	14
P POPULATION INDUCED CONSUMPTION	46		0	36	10	0	0
			<u>DISTRIBUTION (PERCENT)</u>				
			22	57	16	1	4
I INDUSTRY INDUCED CONSUMPTION	41		1	8	32	0	0
			<u>DISTRIBUTION (PERCENT)</u>				
			54	7	30	2	7

Regional Resources and Applicable Technologies

Despite the fact that the ESC region has only 7 percent of the nation's coal reserves, it is the largest regional producer of coal and accounts for 28 percent of the national production. Almost 2.6 quads, over 100 million tons, are exported for use in other regions. Kentucky accounts for 83 percent of regional coal production and 86 percent of regional coal reserves.

Most major highways and railroads in the region have a north-south orientation due to the configuration of the Appalachian Mountains and the Mississippi Valley. The railroads are well developed and capable of handling the transportation of fossil energy raw materials and by-products. However, if coal production should be increased significantly, additional rail spur lines to new mines will have to be built. Marine transportation for fossil energy is excellent via the Ohio and Mississippi Rivers. Transport facilities and access to the Gulf Coast are available at the port cities of Mobile, Alabama, and Biloxi and Gulfport, Mississippi. Oil and gas pipelines also are well developed within the region.

Considering the resources and various transportation systems, Coal Liquefaction, High and Low Btu Gasification, Direct Combustion and Advanced Power Technologies all can be established in the region if environmental and economic constraints are met (Table 28).

Consuming Sectors

A. Industrial

Industry in the ESC region is 26 percent dependent on electricity, reflecting the availability of cheap electric power in the Tennessee Valley. While regional industry uses only 0.1 quad of oil annually, it does consume over 0.5 quad of natural gas.

Low Btu Gasification processes could replace 0.4 quads of natural gas. Direct Combustion has a maximum potential impact of 0.3 quads on industrial oil and gas consumption.

B. Residential/Commercial

The introduction of Coal Liquefaction technology could produce synthetic fuels capable of providing the R/C and Transportation sectors

TABLE 28. EAST SOUTH CENTRAL REGION
FOSSIL ENERGY TECHNOLOGY MATRIX

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS							APPLICATION INDEX
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL			REMARKS		
														AIR	WATER	SOLID WASTE			
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SNG 250 x 10 ⁶ CuFt/day 91,250 x 10 ⁶ Btu/year 1,000 Btu/CuFt 91.25 x 10 ¹² Btu/year OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY NAPHTHA - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	CO ₂ 3,000 PPM TDS 45 TONS/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF CAKING COALS WHICH AGGLOMERATE IN GASIFIERS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	●	
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CuFt/day 91,710 x 10 ⁶ Btu/year 175 Btu/CuFt 91.3 x 10 ¹² Btu/year OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6,468 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5,270 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 24 SOx 70-80 HC 3 CU 2	BOD 30PPM COD 75PPM TDS 250PPM	865 TONS/DAY (9,000 TONS/DAY OF SPENT DOLOMITE IF USED)	• UTILIZATION OF CAKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS OF SCALE-UP. • HIGH CAPITAL INVESTMENT.	●	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (39 MW) 720x10 ³ KWHR/DAY 263x10 ⁶ KWHR/DAY 3,412 Btu/KWHR 0.9 x 10 ¹² Btu/year OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES YR/10 ¹² BTU	UNKNOWN	\$ 70x10 ⁶ to \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 Btu/KWHR	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	17 TONS/DAY	• FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • SORBENT REGENERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.B. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	●	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWHR/DAY 5,563 x 10 ⁶ KWHR/YEAR 3,412 Btu/KWHR 19.2x10 ¹² Btu/YR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	6.1 MGD	DOLOMITE - 486 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 0.2 ACRE YR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGER LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.	●	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ Btu/BARREL 207.0 x 10 ¹² Btu/year OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1.261x10 ⁶ KWHR/YR 3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT MOLYBDENUM 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 65%	1990 - 2000	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	BOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.	●		
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL 49 x 10 ³ BARRELS/DAY 178 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ Btu/BARREL 1 x 10 ¹² Btu/year OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - YR/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 30% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(TONS/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. • RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAR SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	◐	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ⁶ Btu/BARREL 211.7 x 10 ¹² Btu/year OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,489x10 ⁶ KWHR/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 6%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	AMINES 1000PPM CARBONATES 520PPM CHLORIDES 330PPM CHROMATES 130PPM CYANIDES 50PPM ORGANIC ACIDS 1000PPM PHENOLS 60PPM	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A	

REGIONAL RESOURCES AND CHARACTERISTICS	REGIONAL CONSUMPTION (1974)	RESERVES - 29,509,100 x 10 ³ TONS			AUG BTU/TON - 25.0 x 10 ⁶ CAKING PROPERTIES - CARKING PRODUCTION - 164,561 x 10 ³ TONS TRANSPORT (10 ³ TONS) LOADED UNLOADED			RESERVES 366,698 x 10 ³ BARRELS PRODUCTION 72,708 x 10 ³ BARRELS TRANSPORT WILAGE FULL (10 ³ BBL) UNLOADED			RESERVES 2,430,792 x 10 ⁶ Cu. Ft. PRODUCTION 178,545 x 10 ⁶ Cu. Ft. TRANSPORT WILAGE TRANS (10 ⁶ Cu. Ft.)			RESERVES (10 ⁶ TONS)	DISTRIBUTED	DEPLETION RATE 3.2% CONSUMPTION (M.D.) 2,894	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY
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needs for 1.4 quads of gasoline and heating oil. Imports of Oil Shale Technology products from other regions would have a similar impact. High Btu Gasification plants could provide the 0.4 quad needs of the R/C sector as a natural gas substitute.

C. Electric Utility

The electric utility sector is 75 percent dependent on the nation's most abundant resource, coal. As a result, the sector has extremely low Consumption and Dependence Index values of 11 and 12 respectively. Advanced fossil technologies have very limited potential impact (0.1 quad).

Conclusions

Coal Liquefaction and/or Oil Shale liquid substitutes have a potential impact of 1.4 quads in the R/C and Transportation sectors. High Btu Gasification has a maximum possible impact of 0.4 quad in the Residential/-Commercial sector. Direct Combustion and Low Btu Gasification would have a maximum potential impact of 0.3 and 0.5 quads, respectively. Advanced fossil energy technologies do not appear to have as much potential impact in the ESC region as in other regions due to the current high utilization of coal. Such technologies might still be introduced into the ESC region where the resource requirements are met, with the purpose of exporting the products to other regions.

6. West North Central Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the West North Central (WNC) region is given in Table 29. The region consumes relatively small quantities of the less abundant fuels, oil and natural gas. This is reflected in a low Consumption Index value, 73 (Table 30). The region imports coal, oil and natural gas, despite large gas reserves, mostly in Kansas. Both the industrial and residential/commercial sectors are over 60 percent dependent on natural gas.

Regional Resources and Applicable Technologies

About 84 percent of the region's coal reserves are located in Missouri and North Dakota. While the region contains 5 percent of the nation's coal reserves, it accounts only for 2 percent of the national production.

**TABLE 29. WEST NORTH CENTRAL REGION
SUPPLY/DEMAND PROFILE**

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																				NET IMPORTS (FOREIGN & DOMESTIC)			
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM U ₃₀₈ 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S		
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP	
IOWA	2,884,900	0	0	0	0	0	0	FOSSIL 179	590	0	0	890	931		COAL	—	29.0	1.9	108.5	0	139.4	—	21	1	78	0	100%	—	14	1	55	0	16	127.9	380.6	378.1	866.6	
								NUCLEAR 1						ELECT *	(0)	(26.2)	(45.6)	—	—	(71.9)	0	36	63	—	—	100%	0	12	16	—	—	—						
								HYDRO 5	11.5	0	0	11.3	9.9	32.7	NUCLEAR	—	—	—	—	11.3	—	—	—	—	100	—	—	100%	—	—	—	6	—	—	1			
	56,024.8	0	0	0	0										TOTAL	262.5	185.1	246.4	195.9	9.4	899.3	29	21	27	22	1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%		
KANSAS	1,388,100	395,107	11,704,731	0	0	11	29	FOSSIL 134	718	61,691	886,782	7	0		COAL	—	3.4	.1	34.6	0	38.1	—	9	0	91	0	100%	—	1	0	16	0	4	20.5	-57.7	-374.0	-411.1	
								NUCLEAR 0						NG	76.2	207.7	149.9	165.0	—	598.8	13	35	25	27	—	100%	27	80	63	77	—	64						
								HYDRO 1	17.5	357.8	972.8	.1	0	1,348.2	ELECT *	(0)	(21.8)	(42.1)	—	—	(63.9)	0	34	66	—	—	100%	0	9	18	—	—	—					
	33,706.4	2,291.6	12,840.0	0	0										HYDRO	—	—	—	—	.1	—	—	—	—	100	—	—	100%	—	—	—	0	—	—	0			
MINNESOTA	0	0	0	0	0	3	0	FOSSIL 140	0	0	0	736	4,363		NUCLEAR	—	—	—	—	0	—	—	—	—	0	—	100%	—	—	—	0	—	—	0				
								HYDRO 24	0	0	0	6.3	46.5	52.8	NUCLEAR	—	—	—	—	46.5	—	—	—	—	100	—	—	100%	—	—	—	19	—	4				
															TOTAL	324.6	188.0	379.8	241.6	3.3	1,137.3	29	17	33	21	0	100%	100%	100%	100%	100%	100%	100%	100%	100%			
	0	0	0	0	0										COAL	—	36.8	5.1	141.4	.3	183.6	—	20	3	77	0	100%	—	16	1	58	9	16	183.6	540.4	360.5	1,064.5	
MISSOURI	9,487,300	0	0	0	0	1	0	FOSSIL 93	4,623	56	33	1,713	0		OIL	320.9	40.5	167.1	8.9	3.0	540.4	59	7	31	2	1	100%	99	18	37	4	91	47					
								NUCLEAR 0						NG	3.7	110.7	207.6	38.5	—	360.5	1	31	57	11	—	100%	1	48	48	16	—	32						
								HYDRO 7	100.8	.3	0.0	10.6	0	119.7	ELECT *	(0)	(42.3)	(52.9)	—	—	(95.2)	.0	44	56	—	—	100%	0	19	12	—	—	—					
	206,823.1	0	0	0	0										HYDRO	—	—	—	—	18.6	—	—	—	—	100	—	—	100%	—	—	—	5	—	—	1			
NEBRASKA	0	26,779	54,609	0	0	1	2	FOSSIL 83	0	6,611	2,538	1,294	3,996		NUCLEAR	—	—	—	—	0	—	—	—	—	0	—	100%	—	—	—	0	—	—	0				
								HYDRO 18	0	38.3	2.8	15.5	42.6	99.2	NUCLEAR	—	—	—	—	46.5	—	—	—	—	100	—	—	100%	—	—	—	30	—	—	8			
															TOTAL	155.9	89.7	131.5	142.0	2.9	522.0	30	17	25	27	1	100%	100%	100%	100%	100%	100%	100%	100%	100%			
	0	155.3	59.9	0	0										COAL	—	4.5	1.8	72.2	0	78.5	—	6	2	92	0	100%	—	15	3	68	0	31	20.1	-10.0	5.0	-35.1	
NORTH DAKOTA	10,003,000	172,794	432,682	0	0	3	4	FOSSIL 32	7,462	19,697	31,206	2,729	0		OIL	64.2	6.2	31.0	.2	.6	102.2	63	6	30	0	1	100%	100	20	48	0	100	40					
								NUCLEAR 0						NG	0	17.6	21.5	.1	—	39.2	0	45	55	0	—	100%	0	58	33	0	—	15						
								HYDRO 1	106.6	114.2	34.2	34.4	0	289.4	ELECT *	(0)	(2.0)	(10.6)	—	—	(12.6)	0	16	83	—	—	100%	0	7	16	—	—	—					
	226,602.5	1,002.4	474.7	0	0										HYDRO	—	—	—	—	34.4	—	—	—	—	100	—	—	100%	—	—	—	32	—	14				
SOUTH DAKOTA	428,000	0	0	0	0	0	1	FOSSIL 40	0	494	0	5,624	0		NUCLEAR	—	—	—	—	0	—	—	—	—	0	—	100%	—	—	—	0	—	—	0				
								HYDRO 6	0	2.9	0	86.8	0	89.7	NUCLEAR	—	—	—	—	0	—	—	—	—	0	—	100%	—	—	—	89	—	39					
															TOTAL	64.2	28.3	54.3	106.9	.6	254.3	25	11	22	42	0	100%	100%	100%	100%	100%	100%	100%	100%	100%			
	6,060.5	0	0	0	0										COAL	—	.1	.4	6.6	0	7.1	—	1	5	94	0	100%	—	1	1	7	0	3	7.1	93.8	32.8	133.7	
WEST NORTH CENTRAL	30,191,300	594,680	12,192,022	0	0	19	36	FOSSIL 709	13,393	88,549	920,559	12,993	9,290		OIL	1,466.0	123.7	524.4	38.8	23.5	2,176.4	67	6	24	2	1	100%	93	12	31	3	99	41	638.2	1,662.9	1,046.8	3,347.9	
								NUCLEAR 5						NG	188.3	672.2	903.6	362.5	—	2,056.6	6	33	44	18	—	100%	7	63	53	26	—	38						
								HYDRO 62	236.4	513.5	1,009.8	173.0	99.0	2,031.7	ELECT *	(0)	(147.1)	(265.8)	—	—	(412.9)	0	36	64	—	—	100%	0	13	15	—	—	—					
	529,297.3	3,449.1	13,374.6	0	0										HYDRO	—	—	—	—	173.0	—	—	—	—	100	—	—	100%	—	—	—	12	—	3				
														NUCLEAR	—	—	—	—	99.0	—	—	—	—	100	—	—	100%	—	—	—	7	—	2					
														TOTAL	1,584.4	919.3	1,441.1	1,411.0	23.8	5,379.6	29	17	27	26	1	100%	100%	100%	100%	100%	100%	100%	73%	76%	51%	62%		

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

SOURCE: AND U.S. BUREAU OF MINES (1)

TABLE 30
REGIONAL ENERGY MATRIX

WEST NORTH CENTRAL

INDEX	TOTAL	SECTOR	C	O	G	N	H
C CONSUMPTION	73		0	38	35	0	0
			CONSUMPTION (10 ¹⁵ BTU)				
		TRANS 110	0	1.5	0.2	-	-
		INDUS 54	.1	.1	.7	-	-
		R/C 98	0	.5	.9	-	-
		ELEC 29	.7	0	.4	.1	.2
D DEPENDENCE	104		0	54	49	1	0
		TOTAL	DEPENDENCE (PERCENT)				
		TOTAL	16	41	38	2	3
		TRANS 132	0	93	7	-	-
		INDUS 112	13	14	73	-	-
		R/C 129	1	36	63	-	-
		ELEC 40	52	3	26	7	12
P POPULATION INDUCED CONSUMPTION	81		0	52	29	0	0
			DISTRIBUTION (PERCENT)				
			13	53	30	1	3
I INDUSTRY INDUCED CONSUMPTION	52		0	8	44	0	0
			DISTRIBUTION (PERCENT)				
			27	10	56	3	4

Although the region consumed only 0.8 quad of coal, it was forced to import 73 percent of this coal in 1974.

Most of the major rail lines link major cities and industrial centers. Most of the railroad tracks, rolling stock and rail facilities are in good to excellent condition. However, future coal development and conversion, particularly in North Dakota and Missouri, would require new spur lines, rolling stock and coal handling facilities. Road improvements and additional feeder highways may be necessary to support the development of new coal mines and coal conversion facilities. If coal mining were increased and transportation facilities improved, coal conversion techniques could be introduced into the region (Table 31).

High and Low Btu Gasification could be applied in the coal producing states, particularly in North Dakota which has large quantities of surface lignite. Coal from the region or imported from other regions could fuel Coal Liquefaction, Direct Combustion and Advanced Power Systems if the economics are favorable.

Regional production of oil and gas could utilize enhanced oil and gas extraction techniques, increasing the supply of these fuels by as much as 0.8 quad annually.

Consuming Sectors

A. Residential/Commercial

The R/C sector is highly dependent on natural gas and consumes more of this fuel than any of the other WNC regional end-use sectors (0.9 quad). The application of High Btu Gasification technology potentially could eliminate this sector's high dependence on natural gas if economic constraints can be resolved.

The petroleum products consumed by the R/C sector (0.5 quad) potentially could be supplied by liquids from coal liquefaction plants located in the region or oil shale products imported from outside the region.

B. Industrial

The industrial sector, as reflected by the low sector Consumption Index value (54), is not a large consumer of energy. Low Btu Gasification

TABLE 31. WEST NORTH CENTRAL REGION
FOSSIL ENERGY TECHNOLOGY MATRIX

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS							APPLICATION INDEX
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL			REMARKS		
														AIR	WATER	SOLID WASTE			
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SNG 250 x 10 ⁶ CUBIC FT/DAY 91,250 x 10 ⁶ BTU/YEAR 1,000 BTU/CUBIC FT 91.25 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY NAPHTHA - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-88%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 43 TONS/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF CAKING COALS WHICH AGGLOMERATE IN GASIFIERS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	●	
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,423 x 10 ⁶ CUBIC FT/DAY 521,714 x 10 ⁶ BTU/YEAR 175 BTU/CUBIC FT 91.3 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6468 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5279 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 24 SOx 30-40 HC 3 CO 2	BOD 30PPM COD 25PPM TDS 250PPM	865 TONS/DAY (4,000 TONS/DAY OF SPENT DOLOMITE IF USED)	• UTILIZATION OF CAKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS UP SCALE-UP. • HIGH CAPITAL INVESTMENT.	●	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (39 MW) 720x10 ³ KWHR/DAY 263x10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 0.9 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES YR/10 ¹² BTU	UNKNOWN	\$ 20x10 ⁶ to \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 BTU/KWHR	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TON/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	1/ TONS/DAY	• FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • SORBENT REGENERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.R. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	●	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWHR/DAY 5,563 x 10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 19.2x10 ¹² BTU/YR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	43.8x10 ⁶ KWHR/YR	6.1 MGD	DOLOMITE - 486 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE YR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGES LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.	●	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ BTU/BARREL 207.0 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,261x10 ⁶ KWHR/YR	3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT MOLYBDENUM 35 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 63%	1990 - 2000	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	BOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.	●	
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL .49 x 10 ³ BARRELS/DAY 1/8 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ BTU/BARREL 1 x 10 ¹² BTU/YEAR OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - YR/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 30% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(TONS/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. • RELIABILITY OF FRACKING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAR SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	●	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ⁶ BTU/BARREL 211.7 x 10 ¹² BTU/YEAR OTHER PRODUCTS LOAN - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,489x10 ⁶ KWHR/YR	15' MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 67%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 15	AMINES 190PPM CARBONATES 520PPM CHLORIDES 330PPM CHROMATES 130PPM CYANIDES 50PPM ORGANIC ACIDS 1000PPM PHEOLS 60PPM	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A	

REGIONAL RESOURCES AND CHARACTERISTICS	REGIONAL CONSUMPTION (1974)	RESERVES - 30,191,300 x 10 ³ TONS		AUGUSTON - 17.5 x 10 ⁶ CUBIC FT/DAY COKING PROPERTIES - NON-COKING PRODUCTION - 15,995 x 10 ³ TONS		RESERVES 594,680 x 10 ³ BARRELS PRODUCTION 88,549 x 10 ³ BARRELS		RESERVES 12,192,922 x 10 ⁶ CU.FT. PRODUCTION 920,559 x 10 ⁶ CU.FT.		RESERVES (10 ³ TONS) -0-	DISTRIBUTED 121,076 x 10 ⁶ KWHR	DEPLETION RATE CONSUMPTION (M.E.D.) 15.5% 9,125 DOMESTIC 327 MANUFACTURING 195 MINERALS 84 HYDRO-ELECTRIC 194 OTHER 8,425	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	LEGEND: ● APPLICABLE ○ SOME REGIONAL CONSTRAINTS N/A NOT APPLICABLE
		CHARACTERISTICS	UNDERGROUND	SURFACE	TRAIN UNIT TRAIN BARGE TRUCK	GATHERING CRUDE TRUNK PRODUCT	TRANSMISSION DISTRI MAIN	TRANSMISSION DISTRI MAIN	TRANSMISSION DISTRI MAIN									
		10 ³ TONS	8,958,500	21,121,800	5,742 (5,943) 30,348 (NOT AVAIL) 661 6,818 6,800	7,035 10,219 18,297	786 14,338 6,825	7,340 30,439 59,743	920,559 7,953,665 2,024,207									
COAL	874.6 x 10 ¹² BTU	10 ³ TONS	8,958,500	21,121,800	5,742 (5,943) 30,348 (NOT AVAIL) 661 6,818 6,800	7,035 10,219 18,297	786 14,338 6,825	7,340 30,439 59,743	920,559 7,953,665 2,024,207	RESERVES (10 ³ TONS) N/A								
OIL	2,176.4 x 10 ¹² BTU	SULFUR CONTENT ≤ 1.0% 0 1.1% - 3.0% 4% > 3.0% 64% UNKNOWN 32% = 100%	0	26% 52% 12% 10%	5,742 (5,943) 30,348 (NOT AVAIL) 661 6,818 6,800	7,035 10,219 18,297	786 14,338 6,825	7,340 30,439 59,743	920,559 7,953,665 2,024,207	RESERVES (10 ³ TONS) N/A								
NATURAL GAS	2,056.5 x 10 ¹² BTU	COAL TYPE ANTHRACITE 0 BITUMINOUS 100% SUBBITUMINOUS 0 LIGNITE 0 = 100%	0	23% 77%	5,742 (5,943) 30,348 (NOT AVAIL) 661 6,818 6,800	7,035 10,219 18,297	786 14,338 6,825	7,340 30,439 59,743	920,559 7,953,665 2,024,207	RESERVES (10 ³ TONS) N/A								
ELECTRIC POWER	412.9 x 10 ¹² BTU	REMARKS IOWA - NO OIL RESERVES MINNESOTA - NO OIL RESERVES MISSOURI - NO OIL RESERVES SOUTH DAKOTA - NO OIL RESERVES	0	23% 77%	5,742 (5,943) 30,348 (NOT AVAIL) 661 6,818 6,800	7,035 10,219 18,297	786 14,338 6,825	7,340 30,439 59,743	920,559 7,953,665 2,024,207	RESERVES (10 ³ TONS) N/A								

of coal could have some impact on the 0.7 quad of natural gas consumed in this sector.

Direct Combustion technologies could replace, at most, 0.3 quad of natural gas consumption.

C. Electric Utility

The utilities are 52 percent dependent on coal for power generation. Direct Combustion and Advanced Power Systems could be used to increase the utility sector's dependence on coal and potentially replace 0.4 quad of natural gas consumed annually by this sector.

Conclusions

Since the WNC region consumes relatively small quantities of energy, the quantitative impact of advanced fossil energy technologies will not be as large as in some other regions. Coal Liquefaction and liquids from oil Shale imported from outside the region can potentially replace 2.0 quads of petroleum consumption. High Btu Gasification processes could supply another 0.9 quad to alleviate natural gas consumption by the R/C sector. Low Btu Gasification in the industrial sector has a potential impact of 0.5 quad.

Direct Combustion of coal and additional conventional coal use potentially would have an impact on the Industrial and EU sectors' gas consumption of 0.8 quad. Enhanced Oil and Gas Recovery potentially could increase production by 50 percent, adding 0.8 quad of oil and gas to present supplies. The potential impact of Advanced Power Systems using coal on the EU sector is 0.5 quad.

7. West South Central Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the West South Central (WSC) region is given in Table 32. The WSC region, including the States of Arkansas, Louisiana, Oklahoma and Texas, is one of the most concentrated energy producing areas in the world. This region accounts for almost 70 percent of the oil and over 80 percent of the natural gas produced in the nation. Total energy consumption in the WSC region is second only to that of the East North Central region.

TABLE 32. WEST SOUTH CENTRAL REGION
SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																		NET IMPORTS (FOREIGN & DOMESTIC)							
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM U ₃ O ₈ 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S				
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP			
ARKANSAS	665,700	106,336	2,113,404	0	0	4	3	FOSSIL 22	455	16,527	123,975	4,263	361		COAL	—	2.9	0	0	0	2.9	—	100	0	0	0	100%	—	1	0	0	0	0							
								NUCLEAR 1							OIL	193.5	27.7	63.6	43.0	6.3	334.1	58	8	19	13	2	100%	93	12	36	32	100	48	-8.7	238.2	164.3	393.8			
								HYDRO 11	11.6	95.9	136.0	46.9	3.8	294.2	NG	13.8	169.8	76.7	40.0	—	300.3	5	56	26	13	—	100%	7	75	44	30	—	44							
	18,821.6	616.7	2,318.4	0	0										ELECT*	(.1)	(27.0)	(35.6)	—	—	(62.7)	0	43	57	—	—	100%	0	12	20	—	—	—	-300%	71%	55%	57%			
LOUISIANA	0	4,226,514	64,052,445	0	0	22	122	FOSSIL 56	0	737,324	7,753,631	0	0		COAL	—	0	0	0	0	0	—	0	0	0	0	100%	—	0	0	0	0	0							
								NUCLEAR 0							OIL	417.3	86.7	43.2	56.8	10.2	614.2	68	14	7	9	2	100%	84	5	16	14	100	23	0	-3662.3	-6420.8	-10,083.1			
								HYDRO 0	0	4,276.5	8,505.7	0	0	12,782.2	NG	77.8	1491.1	153.1	362.9	—	2084.9	4	72	7	17	—	100%	16	95	57	86	—	77							
	0	24,513.8	70,265.5	0	0										ELECT*	(0)	(72.0)	(73.4)	—	—	(145.4)	0	50	50	—	—	100%	0	5	27	—	—	—	0%	-596%	-308%	-374%			
OKLAHOMA	1,294,200	1,232,377	13,390,312	0	0	12	84	FOSSIL 60	2,356	177,785	1,638,942	3,590	0		COAL	—	4.3	.1	0	0	4.4	—	98	2	0	0	100%	—	1	0	0	0	0							
								NUCLEAR 0							OIL	245.3	24.6	73.2	2.1	2.4	347.6	70	7	21	1	1	100%	91	8	30	1	100	32	-55.1	-683.6	-1,109.3	-1,848.0			
								HYDRO 10	59.5	1,031.2	1,797.9	37.4	0	2,926.0	NG	24.6	241.7	116.4	305.9	—	688.6	4	35	17	44	—	100%	9	82	47	88	—	64							
	32,665.6	7,147.8	14,689.2	0	0										ELECT*	(0)	(24.9)	(55.9)	—	—	(80.8)	0	31	69	—	—	100%	0	8	23	—	—	—	-1252%	-197%	-161%	-171%			
TEXAS	3,271,900	11,001,506	75,540,717	87,800	0	46	358	FOSSIL 158	7,684	1,262,126	8,170,798	1,631	0		COAL	—	42.0	0	75.8	0	117.8	—	36	0	64	0	100%	—	1	0	5	0	2							
								NUCLEAR 0							OIL	1379.0	979.2	217.1	64.6	16.3	2656.2	52	37	8	2	1	100%	94	25	26	4	100	36	16.4	-4664.1	-4377.6	-9025.3			
								HYDRO 21	101.4	7,320.3	8,963.4	17.4	0	16,402.5	NG	95.8	2764.0	364.5	1361.5	—	4585.8	2	60	8	30	—	100%	6	69	43	90	—	62							
	43,189.1	63,808.7	82,868.2	18,877.0	0										ELECT*	(0)	(200.9)	(266.5)	—	—	(467.4)	0	43	57	—	—	100%	0	5	31	—	—	—	14%	-176%	-95%	-122%			
WEST SOUTH CENTRAL	5,231,800	16,566,733	158,096,878	87,300	0	84	567	FOSSIL 296	10,495	2,193,762	17,687,346	9,484	361		COAL	—	49.2	0.1	75.8	0	125.1	—	39	0	61	0	100%	—	1	0	3	0	1							
								NUCLEAR 1							OIL	2235.1	1118.2	397.1	166.5	35.2	3952.1	57	28	10	4	1	100%	91	18	26	7	100	33	-47.4	-8771.8	-11,743.4	-20,562.6			
								HYDRO 42	172.5	12,723.9	19,403.0	101.7	3.8	32,404.9	NG	212.0	4666.6	710.7	2070.3	—	7659.6	3	61	9	27	—	100%	9	76	46	86	—	65							
	94,676.3	96,087.0	173,432.3	18,877.0	0										ELECT*	(0.1)	(324.8)	(431.4)	—	—	(756.3)	0	43	57	—	—	100%	0	5	28	—	—	—	-38%	-222%	-153%	-174%			

ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

SOURCE: AND U.S. BUREAU OF MINES (1)

The WSC region is the largest regional consumer of natural gas; in 1974, the WSC consumed almost one-third of the natural gas utilized in the U.S. Both the Consumption Index value (198) and the Dependence Index value (128), noted in Table 33, are the highest among the nine regions. These values indicate that not only does this region consume the largest quantity of oil and gas of any region, but also that it is more dependent on these fuels than any other region.

The large amount of natural gas used in two major consuming sectors, industry (4.7 quads) and electric utility (2.1 quads), is of major national importance. The industrial sector Consumption Index value (394) and electric utility Consumption Index value (152) are higher than similar sectors in other regions. Also, the industrial sector Dependence Index value (129) and electric utility sector Dependence Index value (120) are exceeded in no other region and reflect great dependence on rapidly depleting energy resources. The Industry-Induced Consumption Index (368) is substantially higher than that of any other region.

Regional Resources and Applicable Technologies

The WSC region is the largest regional producer of oil (about 13 quads) and natural gas (about 19 quads). The region supplies the U.S. with 39 percent of the oil and 86 percent of the natural gas consumed annually. Reserves, from which the oil and natural gas are being extracted, are being depleted at annual rates of 13 percent and 11 percent respectively. Therefore, Oil and Gas Secondary and Tertiary Recovery techniques are exceptionally important to this region (Table 34). Offshore technology is also of primary importance because the Gulf of Mexico is a potential source of large amounts of both oil and natural gas.

Since the region is a major supplier of oil, its oil pipeline network is very well developed. Multiple lines connect the major oil fields within the region with its major cities. Pipelines also extend beyond the region into the major cities and industrial centers of the South, East and West. The natural gas pipeline system is also extensive, connecting the region's gas fields with major cities and industrial areas throughout the United States.

TABLE 33
REGIONAL ENERGY MATRIX

WEST SOUTH CENTRAL

INDEX	TOTAL	SECTOR	C	O	G	N	H
C CONSUMPTION	198		0	68	130	0	0
			<u>CONSUMPTION (10¹⁵ BTU)</u>				
		TRANS 169	0	2.2	.2	-	-
		INDUS 394	0	1.1	4.7	-	-
		R/C 76	0	.4	.7	-	-
		ELEC 152	.1	.2	2.1	0	.1
D DEPENDENCE	128		0	44	84	0	0
			<u>DEPENDENCE (PERCENT)</u>				
		TOTAL	1	33	65	0	1
		TRANS 132	0	91	9	-	-
		INDUS 129	1	19	80	-	-
		R/C 130	0	36	64	-	-
		ELEC 120	3	7	86	0	4
P POPULATION INDUCED CONSUMPTION	118		0	70	48	0	0
			<u>DISTRIBUTION (PERCENT)</u>				
			1	58	40	0	1
I INDUSTRY INDUCED CONSUMPTION	368		0	66	302	0	0
			<u>DISTRIBUTION (PERCENT)</u>				
			1	17	81	0	1

**TABLE 34. WEST SOUTH CENTRAL REGION
FOSSIL ENERGY TECHNOLOGY MATRIX**

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS						APPLICATION INDEX
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL			REMARKS	
														AIR	WATER	SOLID WASTE		
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SHG 250 x 10 ⁶ CUF/DAY 91,250 x 10 ⁶ BTU/YEAR 1,000 BTU/CUFT 91.25 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY WASTES - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ TO \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 43 TONS/10 ¹² BTU	1,250 TONS/DAY	* UTILIZATION OF CAKING COALS WHICH AGGLOMERATE IN GASIFIERS. * DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. * FABRICATION OF LARGE SIZE EQUIPMENT. * POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. * ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. * FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CUF/DAY 521,714 x 10 ⁶ BTU/YEAR 175 BTU/CUFT 91.3 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6480 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5279 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ TO \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 24 SOx 30-40 HC 3 CO 2	BOD 30PPM COD 25PPM TDS 250PPM	865 TONS/DAY (4,000 TONS/DAY OF SPENT DOLOMITE IF USED)	* UTILIZATION OF CAKING COALS. * DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. * CONTINUOUS COAL FEEDING EQUIPMENT. * HIGH TEMPERATURE GAS CLEAN-UP. * CHARACTERIZATION OF PROCESS STREAMS. * CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. * EFFICIENCY OF WATER USAGE. * PROBLEMS OF SCALE-UP. * HIGH CAPITAL INVESTMENT.	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (39 MW) 720x10 ³ KWHR/DAY 263x10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 0.9 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	.23 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES VR/10 ¹² BTU	UNKNOWN	\$ 20x10 ⁶ TO \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 BTU/KWHR	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TON/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	17 TONS/DAY	* FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. * EROSION AND CORROSION OF FLUIDIZED BED TUBES. * SORBENT REGENERATION SYSTEMS. * GAS TURBINE BLADE MATERIALS. * OPERATIONAL DATA ON LARGE-SCALE F.B. COMBUSTION UNITS NOT AVAILABLE. * DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. * COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWHR/DAY 5,563 x 10 ⁶ KWHR/YEAR 3,412 BTU/KWHR 19.2x10 ¹² BTU/YR OTHER PRODUCTS NONE	.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	43.8x10 ⁶ KWHR/YR	6.1 MGD	DOLOMITE - 486 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE VR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ TO \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	* HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. * MATERIALS PROBLEMS. * HOT GAS CLEAN-UP SYSTEMS. * HEAT EXCHANGERS LIVE IN CLOSED CYCLE SYSTEMS. * DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. * LARGE CAPITAL INVESTMENT. * HIGH PARTICULATE EXHAUST EMISSIONS. * DISPOSAL OF CALCIUM SULFATE WASTES.	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ BTU/BARREL 207.0 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,261x10 ⁶ KWHR/YR	3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT POLYBODENUM 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 63%	1990 - 2000	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	BOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	* SOLIDS LIQUIDS SEPARATION. * RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. * IMPROVED CATALYSTS NEEDED. * CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. * IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. * HIGH CAPITAL INVESTMENT.	
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL .49 x 10 ³ BARRELS/DAY 178 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ BTU/BARREL 1 x 10 ¹² BTU/YEAR OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.000 MGD	SURFACTANTS, POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRES - VR/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 30% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT TO 50% TERTIARY RECOVERY IMPROVEMENT 45-75%	PRESENT - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	* ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. * RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. * INADEQUATE DATA BASE ON TAR SANDS. * PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. * HIGH CAPITAL INVESTMENT. * IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. * DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. * POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ⁶ BTU/BARREL 231.7 x 10 ¹² BTU/YEAR OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1,489x10 ⁶ KWHR/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 67%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	AMINES 1900PPM CARBONATES 520PPM CHLORIDES 330PPM CHROMATES 130PPM CYANIDES 50PPM ORGANICS ACIDS 1000PPM PHENOLS 60PPM	SPENT SHALE 108,000 TONS/DAY	* IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. * SHALE CHARACTERISTICS NOT FULLY KNOWN. * OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. * DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. * CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. * WATER QUALITY PROBLEMS. * LARGE CAPITAL INVESTMENTS REQUIRED. * NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A

[illegible]

The WSC has smaller coal reserves (95 quads) than any other region except New England. Lignite reserves are located in Texas and Arkansas and bituminous coal can be found in northwest Texas and Oklahoma.

Major highways in the region have both a north-south and an east-west orientation, with interconnecting highways following no particular pattern. The highway systems appears adequate for future expansion of fossil energy resources and facilities. The railroad network within the region also shows both a north-south and east-west orientation, with major lines radiating from New Orleans, Shreveport, Little Rock, Oklahoma City, Amarillo, Dallas, Fort Worth, Houston, and San Antonio. The railway network is adequate at present for fossil energy transport. However, if many new coal mines and/or coal conversion plants were opened in the region, additional spur tracks, rolling stock and coal-handling facilities would be required. Coal transportation systems must presently be considered a regional constraint to the introduction of coal conversion technologies within the region. Water availability may also be a major constraint to the introduction of coal conversion technologies in some parts of the region.

The conversion of coal to synthetic natural gas could be applied in the region, provided that the regional coal transportation and water availability constraints were overcome. Low Btu Gasification of coal would be particularly useful in this region, where the industrial sector is so highly dependent on natural gas, but this technology is subject to the same regional constraints as mentioned above. The Direct Combustion of high sulfur coal in fluidized bed boilers for electric power generation could help reduce the high dependence of the electric utility sector on natural gas, but it is also subject to the regional transportation and water constraints.

Advanced Power Systems that produce electricity more efficiently and Coal Liquefaction technology are also subject to similar regional constraints.

Consuming Sectors

A. Industrial

Industry in the WSC region consumes one-third of the oil and 44 percent of the natural gas used by all of U.S. industry. This sector uses

nearly 30 percent of the total U.S. industrial energy consumption. The WSC industrial sector consumes about half of the energy used in the region and is the nation's fastest growing industrial sector.

Low Btu gas could potentially replace 3.7 quads of natural gas presently consumed for process heat and steam generation uses. The chemical industry could use intermediate Btu gas as a feedstock.

Direct Combustion of coal in atmospheric fluidized beds or conventional coal burning methods for steam and power generation potentially could replace 2.9 quads of oil and natural gas that is now used by industry for these purposes.

B. Electric Utility

Power generation by the electric utilities consumes 2.1 quads of natural gas and 0.2 quad of oil. Over 50 percent of the natural gas used for electric power generation nationwide was consumed by the WSC region's EU sector. No other regional electric utility sector has developed so large a dependence on natural gas.

A substantial increase in the use of coal for power generation would reduce this dependence. This objective could be reached by converting power facilities from natural gas to coal, making use of conventional coal burning methods and, eventually, Direct Combustion technologies for high sulfur coals and Advanced Power Systems. If all the regional utilities were converted to coal, an annual savings of 2.2 quads of oil and gas could be obtained.

C. Residential/Commercial

The R/C sector consumes 0.7 quad of natural gas and 0.4 quad of oil, accounting for only 9 percent of the energy consumed within the region. High Btu gasification plants producing synthetic natural gas, using coal mined in the region or imported from elsewhere, could be established within the WSC region. However, water availability and coal transportation facilities impose regional constraints. Similar constraints apply to Coal Liquefaction technology which could supply petroleum products to the R/C sector as well as to the transportation sector.

Conclusions

The WSC region is the largest producer of oil and natural gas and also the largest consumer of natural gas. Of the natural gas produced in the region, 39 percent is consumed within the region. While coal conversion technologies could do much to alleviate oil and gas consumption, coal transport systems are presently inadequate in the region, and regional water availability may limit the introduction of these technologies.

Direct Combustion and Low Btu Gasification are the two advanced technologies that have the largest potential impact on oil and gas consumption in the region. The potential impact of the former is estimated at 5.0 quads and the latter, 4.8¹ quads.

Coal Liquefaction technology potentially could provide the 2.6 quads of petroleum products used by R/C and transportation sectors. Such synthetic petroleum products could also be imported from other regions where Coal Liquefaction and Oil Shale technologies had been introduced.

Advanced Power Systems could be used by the EU sector, potentially replacing 2.2 quads of oil and gas utilization. High Btu Gasification could be used to supply 0.7 quad of SNG to the R/C sector.

Enhanced Oil and Gas Recovery can make a very significant contribution to the regional production of oil and natural gas. If these techniques could produce 50 percent more gas and oil, production could be increased by 16.1 quads per year.

8. Mountain Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the Mountain region is given in Table 35. The Mountain (MTN) region has the largest coal reserves in the nation. Despite having almost 40 percent of U.S. coal reserves, the region accounts

¹In other regions, low Btu gas was not assumed to be useful to the electric utility sector since it is easier to burn coal directly. However, since the WSC EU sector is 90 percent dependent on gas, it was assumed that, for this region only, low Btu gas could replace 25 percent of EU sector oil and gas consumption.

TABLE 35. MOUNTAIN REGION SUPPLY/DEMAND PROFILE

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION														NET IMPORTS (FOREIGN & DOMESTIC)								
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)						SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S	
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID./ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP
ARIZONA	350,000	0	0	0	0	1	1	FOSSIL 30	6,448	740	224	7,394	0		COAL	—	2	0	65.7	0	65.9	—	0	0	100	0	100	—	0	0	25	0	10	—	—	—	—
								NUCLEAR 0							OIL	189.5	20.1	35.0	55.4	2.8	302.8	63	7	11	18	1	100	89	18	23	22	100	46	-74.9	298.5	202.1	425.7
								HYDRO 13	140.8	4.3	.2	92.6	0	237.9	NG	22.7	69.9	66.4	43.3	—	202.3	11	35	33	21	—	100	11	62	43	17	—	30	—	—	—	—
	7,644.0	0	0	0	0			TOTAL							ELECT*	(0)	(23.1)	(51.2)	—	—	(74.3)	0	31	69	—	—	100	0	20	34	—	—	—	—	—	—	
COLORADO	14,869,200	289,333	1,881,695	INCLUDED IN COLORADO	480,000,000	2	20	FOSSIL 43	6,897	37,508	144,629	1,414	0		COAL	—	35.6	1.7	111.8	0	149.1	—	24	1	75	0	100	—	23	1	55	0	19	—	—	—	—
								NUCLEAR 0							OIL	224.3	18.4	50.0	6.5	5.3	304.4	74	6	16	2	2	100	99	12	19	3	100	38	-4.8	86.9	162.1	244.4
								HYDRO 29	193.9	217.5	158.7	18.3	0	548.4	NG	2.5	89.0	163.5	66.0	—	321.0	1	28	51	20	—	100	1	57	63	33	—	41	—	—	—	—
	331,965.9	1,678.1	2,064.2	0	2,640,000.0			TOTAL							ELECT*	(0)	(12.5)	(42.7)	—	—	(55.2)	0	23	77	—	—	100	0	8	17	—	—	—	—	—	—	
IDAHO	0	0	0	0	0	0	0	FOSSIL 5	0	0	0	9,686	0		COAL	—	7.2	3.0	0	0	10.2	—	71	29	0	0	100	—	10	4	0	0	3	—	—	—	—
								NUCLEAR 0							OIL	73.8	9.9	30.1	.3	2.7	116.8	63	9	26	0	2	100	96	14	39	0	100	41	10.7	116.8	64.1	101.2
								HYDRO 37	0	0	0	107.0	0	107.0	NG	4.1	32.0	18.1	0	—	54.2	8	54	13	0	—	100	5	45	24	0	—	19	—	—	—	—
	0	0	0	0	0			TOTAL							ELECT*	(0)	(21.1)	(25.7)	—	—	(46.8)	0	45	55	—	—	100	0	30	33	—	—	—	—	—	—	
MONTANA	108,396,200	207,389	901,260	0	0	7	4	FOSSIL 9	14,106	34,554	54,873	9,724	0		COAL	—	1.2	.2	13.2	0	14.6	—	8	1	91	0	100	—	1	0	11	0	4	—	—	—	—
								NUCLEAR 0							OIL	84.9	22.4	23.1	.3	2.2	132.9	64	17	17	0	2	100	98	22	31	0	100	38	-289.8	-67.5	37.1	-320.2
								HYDRO 21	304.4	200.4	60.2	107.4	0	672.4	NG	1.8	54.5	39.0	2.0	—	97.3	2	56	40	2	—	100	2	54	52	2	—	28	—	—	—	—
	2,336,058.7	1,202.9	988.7	0	0			TOTAL							ELECT*	(.1)	(22.7)	(13.1)	—	—	(35.9)	0	63	37	—	—	100	0	23	17	—	—	—	—	—	—	
NEVADA	0	0	0	0	0	1	0	FOSSIL 20	0	129	0	1,600	0		COAL	—	2.7	0	98.9	0	101.6	—	3	0	97	0	100	—	11	0	64	0	36	—	—	—	—
								NUCLEAR 0							OIL	73.5	3.8	12.3	4.4	.1	94.1	78	4	13	5	0	100	100	15	22	3	100	34	101.6	93.4	67.5	262.6
								HYDRO 7	0	.7	0	17.9	0	18.6	NG	0	10.6	24.0	32.9	—	67.5	0	16	35	49	—	100	0	41	42	21	—	24	—	—	—	—
	0	0	0	0	0			TOTAL							ELECT*	(0)	(8.4)	(20.5)	—	—	(28.9)	0	29	71	—	—	100	0	33	36	—	—	—	—	—	—	
NEW MEXICO	4,394,800	624,968	11,944,902	605,400	0	7	31	FOSSIL 26	9,393	98,695	1,244,779	73	0		COAL	—	.2	0	136.5	0	136.7	—	0	0	100	0	100	—	0	0	64	0	24	—	—	—	—
								NUCLEAR 0							OIL	118.3	16.2	22.9	7.9	4.2	169.5	70	10	13	5	2	100	78	12	25	4	100	29	-80.1	-402.9	-1,097.3	-1,580.4
								HYDRO 1	216.8	572.4	1,365.5	.8	0	2,155.5	NG	33.0	114.6	51.6	69.0	—	268.2	12	43	19	26	—	100	22	84	56	32	—	47	—	—	—	—
	101,437.3	3,624.8	13,103.6	130,161.0	0			TOTAL							ELECT*	(0)	(6.1)	(17.2)	—	—	(24.0)	0	26	75	—	—	100	0	4	19	—	—	—	—	—	—	
UTAH	4,042,500	250,648	1,031,049	68,400	90,000,000	8	7	FOSSIL 17	5,858	39,363	50,522	941	0		COAL	—	64.2	6.7	34.9	0	105.8	—	61	6	33	0	100	—	38	6	68	0	25	—	—	—	—
								NUCLEAR 0							OIL	106.9	34.5	30.5	.9	2.3	175.1	61	20	17	1	1	100	99	20	27	2	100	42	-43.2	-53.2	69.2	-27.2
								HYDRO 46	149.0	228.3	55.4	12.0	0	444.7	NG	.6	63.4	57.3	3.3	—	124.6	0	51	46	3	—	100	1	37	51	6	—	30	—	—	—	—
	102,841.2	1,453.8	1,131.5	14,706.0	485,000.0			TOTAL							ELECT*	(0)	(8.5)	(18.3)	—	—	(26.8)	0	32	68	—	—	100	0	5	16	—	—	—	—	—	—	
WYOMING	53,336,100	903,360	3,917,387	478,000	30,000,000	11	29	FOSSIL 18	20,702	139,997	326,657	1,411	0		COAL	—	9.8	.5	110.4	0	120.7	—	8	0	92	0	100	—	8	1	85	0	34	—	—	—	—
								NUCLEAR 0							OIL	64.2	18.2	17.8	1.2	.9	102.3	63	18	17	1	1	100	89	16	34	1	100	29	-306.2	-709.7	-242.2	-1,258.1
								HYDRO 13	426.9	812.0	358.3	16.9	0	1,614.1	NG	7.7	81.6	25.8	1.0	—	116.1	7	70	22	1	—	100	11	70	49	1	—	32	—	—	—	—
	1,099,790.3	5,239.5	4,747.4	107,770.0	166,000.0			TOTAL							ELECT*	(0)	(7.0)	(8.6)	—	—	(15.6)	0	45	55	—	—	100	0	6	16	—	—	—	—	—	—	
MOUNTAIN	185,388,800	2,275,698	19,676,653	1,151,800	600,000,000	30	92	FOSSIL 168	63,404	350,986	1,821,684	32,243	0		COAL	—	121.1	12.1	571.5	0	704.7	—	17	2	81	0	100	—	14	1	46	0	19	—	—	—	—
								NUCLEAR 0							OIL	935.4	143.5	221.7	76.8	20.5	1,397.9	67	10	16													

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

SOURCE: AND U.S. BUREAU OF MINES (1

for only 9 percent of the coal production. At the present rate of coal consumption, the MTN region has enough reserves to meet the nation's needs for over three centuries.

The MTN region also has significant oil and natural gas reserves. The MTN region is the only region besides the WSC to export oil and gas. It is also the sole national producer of uranium and contains the only oil shale resources assayed at over 25 gallons per ton.

Only New England consumes less total energy than the Mountain states; no region consumes less petroleum. The industrial, R/C and electric utility sectors use very little oil (0.4 quad) and only moderate quantities of gas (1.2 quads). These factors are reflected in low values for Consumption, Population-Induced Consumption and Industry-Induced Consumption Indices (Table 36). Also the Dependence Index 93, is below the national average.

Regional Resources and Applicable Technologies

The MTN region is the most sparsely populated of the nine U.S. Census regions. It includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming, covers 863,787 square miles and has a population of 8.5 million, only slightly higher than the population of New York City. The region has coal reserves of 185 billion tons, of which 58 percent is located in Montana and almost 29 percent in Wyoming. Idaho and Nevada have no fossil energy reserves, and Arizona has only small quantities of coal.

Most of the coal found in the region has a sulfur content of less than 1 percent. This important source of low sulfur coal is currently being mined at a very low rate. Coal production will have to be increased substantially before coal conversion technologies can be introduced within the region.

The highway and railway networks in the Mountain region are naturally influenced by the Rocky Mountains. The few north-south highway and railroad lines run along the eastern border of the mountains, and the major east-west routes follow the mountain passes. Denver, Salt Lake City, and Albuquerque are the primary transportation centers in the region. Large-scale development of coal mines and the establishment of coal conversion

TABLE 36
REGION ENERGY MATRIX

MOUNTAIN

INDEX	TOTAL	SECTOR	C	O	G	N	H
U CONSUMPTION	46		0	25	21	0	0
			CONSUMPTION (10 ¹⁵ BTU)				
		TRANS 70	0	.9	.1	-	-
		INDUS 45	.1	.1	.5	-	-
		R/C 46	0	.2	.4	-	-
		ELEC 21	.6	.1	.2	0	.4
D DEPENDENCE	93		0	50	43	0	0
			DEPENDENCE (PERCENT)				
		TOTAL	19	37	34	0	10
		TRANS 132	0	93	7	-	-
		INDUS 110	16	18	66	-	-
		R/C 128	2	33	65	-	-
		ELEC 32	46	6	18	0	30
P POPULATION INDUCED CONSUMPTION	46		0	31	15	0	0
			DISTRIBUTION (PERCENT)				
			16	50	24	0	10
I INDUSTRY INDUCED CONSUMPTION	42		0	10	32	0	0
			DISTRIBUTION (PERCENT)				
			27	14	48	0	11

plants in the northern and southern portions of the region would require additional rail lines and facilities to handle and transport coal. Also, problems associated with rapid increases in local population would have to be addressed.

With regard to water availability, parts of Wyoming, Colorado and New Mexico have annual water depletion rates of 70-90 percent, while parts of Arizona have annual water depletion rates of greater than 90 percent. Coal conversion technologies may be introduced into the region provided that water resources be secured (Table 37). The four corners area and the State of Montana are regions of particular interest for coal and oil shale development. In these areas annual water depletion rates are less than 20 percent. Hence, the regional constraint of water availability will not be so severe as in the more arid areas of the MTN region.

The oil and gas pipeline network is presently limited due to the lack of major industrial centers. Connections with major pipeline systems would have to be made in order to transport liquids and gases from coal conversion and oil shale technologies. With the introduction of these technologies, the MTN region could become the energy center of the nation, exporting synthetic petroleum and natural gas as well as coal and uranium to other regions of the country.

Enhanced Oil and Gas Recovery techniques have application to this region. The potential impact of these technologies is estimated at 1 quad each for oil and natural gas.

Consuming Sectors

A. Residential/Commercial

Coal Liquefaction and Oil Shale technologies could supply the transportation and R/C sectors with the equivalent of 1.2 quads of petroleum. High Btu Gasification could replace 0.4 quad of natural gas consumption in the R/C sector.

B. Industrial

Industry does not consume much energy in the MTN region (0.8 quad total). Low Btu Gasification could be used for industrial process heat and process steam in major cities within the region with a potential impact of

**TABLE 37. MOUNTAIN REGION
FOSSIL ENERGY TECHNOLOGY MATRIX**

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS					APPLICATION INDEX	
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL				REMARKS
														AIR	WATER	SOLID WASTE		
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SHG 250 x 10 ⁶ CUBIC FEET/DAY 91,250 x 10 ⁶ BTU/YEAR 1,000 BTU/CUBIC FEET 91.25 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY NAPHTHA - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 43 TONS/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF COKING COALS WHICH AGGLOMERATE IN GASIFIERS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.	
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CUBIC FEET/DAY 521,710 x 10 ⁶ BTU/YEAR 175 BTU/CUBIC FEET 91.3 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6480 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 145 x 10 ³ TONS/DAY 5270 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 24 SOx 30-40 HC 3 CO 2	BOD 30PPM COD 25PPM TDS 250PPM	865 TONS/DAY (4,000 TONS/DAY OF SPENT DOLOMITE IF USED)	• UTILIZATION OF COKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS OF SCALE-UP. • HIGH CAPITAL INVESTMENT.	
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (39 MW) 720x10 ³ KWH/DAY 203x10 ⁶ KWH/YEAR 5,412 BTU/KWH 0.9 x 10 ¹² BTU/YEAR OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 90.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES YR/10 ¹² BTU	UNKNOWN	\$ 20x10 ⁶ to \$30x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 BTU/KWH	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TONS/10 ¹² BTU TDS 10.2 TONS/10 ¹² BTU	17 TONS/DAY	• FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • SORBENT REGENERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.B. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.	
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWH/DAY 5,563 x 10 ⁶ KWH/YEAR 5,412 BTU/KWH 19.2x10 ¹² BTU/YEAR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	43.0x10 ⁶ KWH/YR	6.1 MGD	DOLOMITE 486 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE YR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGER LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.	
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ BTU/BARREL 207.0 x 10 ¹² BTU/YEAR OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1.261x10 ⁶ KWH/YR	3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT MOLYBDENUM 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 63%	1990 - 2000	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	HOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.	
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL 149 x 10 ³ BARRELS/DAY 378 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ BTU/BARREL 1 x 10 ¹² BTU/YEAR OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - YR/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 50% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(TONS/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. • RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAR SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.	
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ⁶ BTU/BARREL 211.7 x 10 ¹² BTU/YEAR OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1.489x10 ⁶ KWH/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 67%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	AMINES 190PPM CARBONATES 520PPM CHLORIDES 330PPM CHROMATES 130PPM CYANIDES 50PPM ORGANICS ACIDS 1000PPM PHENOLS 60PPM	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	

REGIONAL RESOURCES AND CHARACTERISTICS	REGIONAL CONSUMPTION (1974)	RESERVES - 185,388,800 x 10 ³ TONS		ADD BTU/TON - 21.5 x 10 ⁶ COKING PROPERTIES - NON-COKING PRODUCTION - 63,400 x 10 ³ TONS		RESERVES PRODUCTION 2,275,698 x 10 ³ BARRELS 350,986 x 10 ³ BARRELS		RESERVES PRODUCTION 19,676,853 x 10 ⁶ Cu.Ft. 1,821,684 x 10 ⁶ Cu.Ft.		RESERVES (10 ³ TONS) 600,000,000	DISTRIBUTED 90,162 x 10 ⁶ KWH	DEPLETION RATE 21.7% CONSUMPTION (M.G.D.) 30,789	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	LEGEND: ● APPLICABLE ○ SOME REGIONAL CONSTRAINTS N/A NOT APPLICABLE
		CHARACTERISTICS	UNDEVELOPED	SURFACE	TRAIN UNIT/TON	GALETON/TON	GALETON/TON	GALETON/TON	GALETON/TON										
COAL	704.7 x 10 ¹² Btu	10 ³ TONS	115,241,200	70,147,600	47,469 (27,871)	19,674 (NOT AVAILABLE)	1,686	15,644	44,155	35,818									
OIL	1,397.9 x 10 ¹² Btu	SULFUR CONTENT <1.0% 1.0% - 3.0% >3.0% UNKNOWN	64% 8% 2% 26%	77% 19% 1% 3%	0	1,686	15,644	44,155	35,818										
NATURAL GAS	1,251.1 x 10 ¹² Btu	COAL TYPE	0 18% 82%	0 2% 88%	0	1,686	15,644	44,155	35,818										
ELECTRIC POWER	307.6 x 10 ¹² Btu	AROMATIC BITUMINOUS SUBBITUMINOUS LIGNITE	0 18% 82%	0 2% 88%	0	1,686	15,644	44,155	35,818										
REMARKS - ARIZONA - NO OIL RESERVES IDAHO - NO OIL RESERVES NEVADA - NO OIL RESERVES																			
REMARKS - ARIZONA - NO GAS RESERVES IDAHO - NO GAS RESERVES NEVADA - NO GAS RESERVES																			
REMARKS - MOST OF THE MOUNTAIN REGION SUFFERS FROM A HIGH WATER DEPLETION RATE																			
REMARKS - COLORADO - UTAH - NEW MEXICO																			

0.5 quad. Direct Combustion technologies have a potential impact of 0.3 quad on industrial oil and gas consumption.

C. Electric Utility

Being 46 percent dependent on coal and 30 percent dependent on hydro power, the EU sector consumes only 0.3 quad of oil and gas. However, coal-oil slurries and fuel substitution can be applied whenever possible to conserve resources of oil and gas. Since 77 percent of the surface coal has less than 1 percent sulfur, it would be easier to use conventional coal fired electric plants than Direct Combustion fluidized beds for electric power. Advanced Power Systems could replace 0.3 quad of oil and gas consumption by the EU sector.

Conclusions

The Mountain region is not particularly significant in terms of the energy that it consumes. However, it is particularly noteworthy because of the potential energy supply that could be derived from the region. Technologies developed within this region would be producing energy not only for use within the region but also for export to other regions.

9. Pacific Region

Review of Significant Energy Characteristics

The Supply/Demand Profile for the Pacific (PAC) region is given in Table 38. The PAC region, including California, Oregon, Washington, Alaska and Hawaii, is the largest region in terms of land area and one of the most varied in terms of energy characteristics. The States' fossil resources range from 0 in Hawaii through the moderate, well-developed oil and natural gas resources of California, to the rich Alaskan oil and gas reservoirs. Consumption patterns vary from California, which consumes over 5 quads of energy, to Hawaii, which is almost totally dependent on 0.2 quad of imported oil. Coal production and utilization throughout the region are insignificant (0.1 quad).

Overall, the region consumed 7.7 quads of energy in 1974; 47 percent was in the form of oil, of which 68 percent was attributed to the transportation sector. Regional industry and the R/C sector are highly dependent on natural gas. The electric utility sector produces 1.6 quads

**TABLE 38. PACIFIC REGION
SUPPLY/DEMAND PROFILE**

CHARACTERISTICS STATE	ENERGY RESERVES					PROCESSING (NUMBER)			PRIMARY RESOURCE PRODUCTION						CONSUMPTION																		NET IMPORTS (FOREIGN & DOMESTIC)							
	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	URANIUM U ₃ O ₈ 10 ³ LBS.	OIL SHALE 10 ³ TONS	OIL REFINERY	NATURAL GAS PLANT	ELECTRIC POWER PLANT	COAL 10 ³ TONS	OIL 10 ³ BARRELS	GAS 10 ⁶ Cu.Ft.	HYDRO ELECTRIC 10 ⁶ KWHR	NUCLEAR ELECTRIC 10 ⁶ KWHR	TOTAL	TOTAL PRIMARY RESOURCE REQUIREMENTS TOTAL (10 ¹² BTU'S)							SECTOR PERCENTAGE OF TOTAL FUEL UTILIZATION						PERCENTAGE FUEL DEPENDENCY BY SECTOR						COAL 10 ¹² BTU'S	OIL 10 ¹² BTU'S	NATURAL GAS 10 ¹² BTU'S	TOTAL IMPORTS 10 ¹² BTU'S			
	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S				10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	10 ¹² BTU'S	ENERGY SOURCE	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	TRANS.	INDUST.	RESID/ COMM.	ELECTRIC UTILITY	MISC.	TOTAL	% OF COAL CONSUMP	% OF OIL CONSUMP	% OF NATURAL GAS CONSUMP	% OF TOTAL CONSUMP			
ALASKA	11,645,400	10,094,099	31,866,612	0	0	2	2	FOSSIL 40	700	70,603	128,935	326	0		COAL	—	9.5	.3	0	0	9.8	—	100	0	0	0	100%	—	19	1	0	0	6	-6.2	-313.2	-75.6	-395.0			
								NUCLEAR 0							OIL	63.7	9.1	20.0	2.4	1.1	96.3	66	9	21	3	1	100%	100	18	46	10	100	55							
								HYDRO 14	16.0	409.5	141.4	4.2	0		NG	.1	30.5	17.6	17.6	—	65.8	0	46	27	27	—	100%	0	61	40	73	—	37							
									266,213.8	58,545.7	34,947.7	0	0								ELECT*	(0)	(.7)	(5.8)	—	(6.5)	0	11	89	—	—	100%	0				2	13	—	—
CALIFORNIA	0	3,557,036	5,194,592	0	0	37	44	FOSSIL 62	0	323,003	365,354	46,420	2,861		COAL	—	55.5	0	0	0	55.5	—	100	0	0	0	100%	—	5	0	0	0	1	55.5	657.8	1,518.0	2,231.3			
								NUCLEAR 2							OIL	1,749.5	166.5	152.0	447.6	15.7	2,531.3	69	6	6	18	1	100%	99	14	12	35	100	50							
								HYDRO 168	0	1,873.4	400.8	495.7	30.5		NG	19.4	761.9	826.0	311.5	—	1,918.8	1	40	43	16	—	100%	1	66	62	24	—	38							
									0	20,630.8	5,698.5	0	0								ELECT*	(.7)	(175.4)	(347.7)	—	(523.7)	0	34	66	—	—	100%	0				15	26	—	—
HAWAII	0	0	0	0	0	1	0	FOSSIL 19	0	0	0	18	0		COAL	—	0	0	0	0	0	—	0	0	0	0	100%	—	0	0	0	0	0	0	184.7	0	184.7			
								NUCLEAR 0							OIL	107.5	10.6	5.9	57.3	3.4	184.7	58	6	3	31	2	100%	100	53	38	100	100	100							
								HYDRO 2	0	0	0	.2	0		NG	0	0	0	0	—	0	0	0	0	—	100%	0	0	0	0	—	0								
									0	0	0	0	0								ELECT*	(0)	(9.4)	(9.8)	—	(19.2)	0	49	51	—	—	100%	0				—	92	—	—
OREGON	1,800	0	0	0	0	0	0	FOSSIL 8	0	0	0	35,964	0		COAL	—	3.6	.2	0	0	3.8	—	95	5	0	0	100%	—	2	0	0	0	1	3.8	309.1	106.3	419.2			
								NUCLEAR 0							OIL	201.6	33.2	67.7	5.1	1.5	309.1	65	11	22	2	0	100%	96	22	39	2	100	48							
								HYDRO 50	0	0	0	228.5	0		NG	7.5	62.5	36.0	.3	—	106.3	7	59	34	0	—	100%	4	42	21	0	—	16							
									34.8	0	0	0	0								ELECT*	(0)	(49.6)	(69.4)	—	(119.0)	0	42	58	—	—	100%	0				33	40	—	—
WASHINGTON	1,064,000	0	0	0	0	6	0	FOSSIL 10	3,913	0	0	82,303	3,889		COAL	—	5.2	.2	59.4	0	64.8	—	0	0	92	0	100%	—	2	0	0	0	2	-10.9	440.0	188.2	617.3			
								NUCLEAR 1							OIL	299.3	53.7	84.1	.4	2.5	440.0	68	12	19	0	1	100%	98	19	32	0	100	27							
								HYDRO 51	75.7	0	0	879.1	41.5		NG	5.6	112.4	70.2	0	—	188.2	3	60	37	0	—	100%	2	41	26	0	—	12							
									37,790.4	0	0	0	0								ELECT*	(0)	(105.4)	(111.5)	—	(217.0)	0	49	51	—	—	100%	0				38	42	—	—
PACIFIC	13,601,200	13,651,135	37,061,204	0	0	46	46	FOSSIL 141	4,613	393,606	494,289	165,031	6,750		COAL	—	73.8	.7	59.4	0	133.9	—	55	1	44	0	100%	—	4	0	2	0	2	42.2	1,278.5	1,736.8	3,057.5			
								NUCLEAR 3							OIL	2,421.6	273.1	329.7	512.8	24.2	3,561.4	68	8	9	14	1	100%	99	17	18	20	100	46							
								HYDRO 285	91.7	2,282.9	542.2	1,607.7	72.0		NG	32.6	967.2	949.8	329.4	—	2,279.0	1	82	42	15	—	100%	1	58	52	13	—	30							
									304,039.0	79,176.6	40,666.2	0	0								ELECT*	(.7)	(340.5)	(544.3)	—	(855.5)	0	38	62	—	—	100%	0				21	30	—	—
															HYDRO	—	—	—	1,607.7	—	1,607.7	—	—	100	—	100%	—	—	—	62	—	21	-17%	100%	100%	34%				
															NUCLEAR	—	—	—	72.0	—	72.0	—	—	100	—	100%	—	—	—	3	—	1								
															TOTAL	2,454.2	1,314.1	1,280.2	2,581.3	24.2	7,654.0	32	17	17	34	0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%				

*ELECTRICITY DISTRIBUTED IS NOT INCLUDED IN THE TOTALS

SOURCE: AND U.S. BUREAU OF MINES (1

hydroelectrically, more than any other EU regional sector. Consumption and Dependence Indices are close to the national average (Table 39). The Population-Induced Consumption Index is above the national average and the Industry-Induced Consumption Index below.

The PAC region imports large amounts of oil (1.3 quads) and natural gas (1.7 quads). The development of Alaskan resources will probably result in the region exporting large quantities of both oil and gas.

Regional Resources and Applicable Technologies

Only the West South Central region has larger oil and natural gas reserves than the Pacific region. The combined resources of Alaska and California total 40 percent of the nation's oil reserves and 16 percent of the natural gas reserves. Alaska contains 74 percent of the oil reserves and 86 percent of the natural gas reserves in the PAC region. However, development of Alaska's reserves has just begun. A resource appraisal, particularly in Alaska and the Outer Continental Shelf, will enable a more accurate determination of the extent of the oil and gas reserves within the region. It is difficult, at present, to determine the extent to which Enhanced Oil and Gas Recovery techniques will contribute to oil and gas production within the region (Table 40). Secondary and Tertiary, as well as offshore, techniques will probably have ultimate importance to production within the region.

Energy reserves in the form of coal are about 2.5 times greater than the oil and natural gas reserves combined. Still, coal production is low because 86 percent of these reserves are in Alaska, which has not developed an extensive coal mining industry. If the use of coal is to increase in the PAC region, rail and marine facilities, especially those required to handle Alaskan coal, will have to be developed extensively. The PAC region, therefore, has a regional constraint associated with coal handling and transportation facilities. The introduction of all of the coal conversion technologies will be inhibited until such coal transportation systems are developed. Other energy transportation systems are reasonably well developed in the region.

TABLE 39
REGIONAL DESCRIPTIVE MATRIX

PACIFIC

INDEX	TOTAL	SECTOR	C	O	G	N	H
U CONSUMPTION	101		0	62	39	0	0
			CONSUMPTION (10 ¹⁵ BTU)				
		TRANS 170	0	2.4	0.	-	-
		INDUS 85	.1	.3	1.0	-	-
		R/C 87	0	.3	.9	-	-
		ELEC 59	.1	.5	.3	.1	1.6
D DEPENDENCE	100		0	62	38	0	0
			DEPENDENCE (PERCENT)				
		TOTAL	2	46	30	1	21
		TRANS 132	0	99	1	-	-
		INDUS 123	6	21	73	-	-
		R/C 130	0	26	74	-	-
		ELEC 44	2	20	13	3	62
P POPULATION INDUCED CONSUMPTION	109		0	80	29	0	0
			DISTRIBUTION (PERCENT)				
			1	57	22	1	19
I INDUSTRY INDUCED CONSUMPTION	87		0	27	60	0	0
			DISTRIBUTION (PERCENT)				
			4	21	47	1	27

TABLE 40. PACIFIC REGION
FOSSIL ENERGY TECHNOLOGY MATRIX

TECHNOLOGY	OUTPUT	RESOURCE REQUIREMENTS										PROBLEMS AND CONSTRAINTS					APPLICATION INDEX		
		COAL	OIL	NATURAL GAS	OIL SHALE	ELECTRIC POWER	WATER	OTHER MATERIALS	LAND	LABOR	CAPITAL	ENERGY EFFICIENCY	TIMING OF INTRODUCTION	ENVIRONMENTAL				REMARKS	
														AIR	WATER	SOLID WASTE			
HIGH BTU GASIFICATION	PRIMARY PRODUCT - SNG 250 x 10 ⁶ CuFt/day 91,250 x 10 ⁶ Btu/year 1,000 Btu/CuFt 91.25 x 10 ¹² Btu/year OTHER PRODUCTS AMMONIA - 120 TONS/DAY SULFUR - 110 TONS/DAY TAR - 0.1 x 10 ¹² TONS/DAY NAPHTHA - 60,000 GALLONS/DAY	20.1 x 10 ³ TONS/DAY 7,325 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 16.7 x 10 ³ TONS/DAY 6,094 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	20 MGD	NICKEL - 101 LBS/DAY	FACILITY - 350 ACRES	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	PRIMARY 54%-68%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 70 SOx 50 HC 1 CO 4	COD 3,000 PPM TDS 45 TONS/10 ¹² BTU	1,250 TONS/DAY	• UTILIZATION OF COKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURE AND PRESSURE. • FABRICATION OF LARGE SIZE EQUIPMENT. • POLLUTANT AND SAFETY PROBLEMS NEED TO BE IDENTIFIED. • ENVIRONMENTAL PROBLEMS ARE MAGNIFIED DUE TO THE LARGE SIZE OF COMMERCIAL PLANTS. • FEDERAL INCENTIVES MAY BE NEEDED TO REDUCE FINANCIAL CONSTRAINTS.		
LOW BTU GASIFICATION	PRIMARY PRODUCT - LOW BTU GAS 1,429 x 10 ⁶ CuFt/day 521,714 x 10 ⁶ Btu/year 175 Btu/CuFt 91.3 x 10 ¹² Btu/year OTHER PRODUCTS NONE	17.8 x 10 ³ TONS/DAY 6488 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 14.5 x 10 ³ TONS/DAY 5279 x 10 ³ TONS/YEAR (EASTERN COAL 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.4 MGD	DOLOMITE - 4,000 TONS/DAY (FOR FLUIDIZED BED PROCESS)	FACILITY - 350 ACRES	UNKNOWN	\$ 100x10 ⁶ to \$600x10 ⁶	PRIMARY 73%-95%	1980 - 1985	(TONS/10 ¹² BTU INPUT) PARTICULATES 5 NOx 24 SOx 30-40 HC 3 CO 2	BOD 30PPM COD 25PPM TDS 250PPM	865 TONS/DAY (4,000 TONS/DAY OF SPENT DOLOMITE IF USED)	• UTILIZATION OF COKING COALS. • DEVELOPMENT OF MATERIALS FOR USE AT HIGH TEMPERATURES AND PRESSURES. • CONTINUOUS COAL FEEDING EQUIPMENT. • HIGH TEMPERATURE GAS CLEAN-UP. • CHARACTERIZATION OF PROCESS STREAMS. • CONTROL OF TRACE ELEMENTS AND FINE PARTICULATES. • EFFICIENCY OF WATER USAGE. • PROBLEMS OF SCALE-UP. • HIGH CAPITAL INVESTMENT.		
DIRECT COMBUSTION	PRIMARY PRODUCT - ELECTRIC POWER (30 MW) 720x10 ³ KWH/DAY 263x10 ⁶ KWH/DAY 3,412 Btu/KWH 0.9 x 10 ¹² Btu/year OTHER PRODUCTS NONE	.33 x 10 ³ TONS/DAY 120 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) .27 x 10 ³ TONS/DAY 99.8 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	UNKNOWN	0.3 MGD	LIMESTONE 1.27 TONS/DAY	TOTAL LAND IMPACT - 4.28 ACRES YR/10 ¹² BTU	UNKNOWN	\$ 70x10 ⁶ to \$10x10 ⁶	THERMAL - 37% HEAT RATE - 9,200 Btu/KWH	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 11 NOx 70 SOx 378 HC 240	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	17 TONS/DAY	• FEED ASH DISPOSAL AND HOT GAS CLEAN-UP SYSTEMS YET TO BE DEVELOPED. • EROSION AND CORROSION OF FLUIDIZED BED TUBES. • DURABLE AERATION SYSTEMS. • GAS TURBINE BLADE MATERIALS. • OPERATIONAL DATA ON LARGE-SCALE F.B. COMBUSTION UNITS NOT AVAILABLE. • DISPOSAL OF LARGE QUANTITIES OF SOLID WASTE. • COAL-OIL SLURRY RETROFIT PRESENTS AN ENVIRONMENTAL PROBLEM.		
ADVANCED POWER SYSTEMS	PRIMARY PRODUCT - ELECTRIC POWER (635 MW) 15,240x10 ³ KWH/DAY 5,563 x 10 ⁶ KWH/YEAR 3,412 Btu/KWH 19.2x10 ¹² Btu/YR OTHER PRODUCTS NONE	7.1 x 10 ³ TONS/DAY 2,574 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 5.9 x 10 ³ TONS/DAY 2,141 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	43.8x10 ⁶ KWH/YR	6.1 MGD	DOLOMITE - 486 TONS/DAY	FACILITY - 60 ACRES TOTAL LAND IMPACT 4.2 ACRE YR/10 ¹² BTU	UNKNOWN	\$ 500x10 ⁶ to \$1,000x10 ⁶	THERMAL - 36% HEAT RATE - 9,500	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 67 SOx 441	ORGANICS 0.003 TONS/10 ¹² BTU TDS 18.2 TONS/10 ¹² BTU	ASH AND SORBENT 980 TONS/DAY	• HIGH TEMPERATURE TURBINE COOLING SYSTEMS NEEDED. • MATERIALS PROBLEMS. • HOT GAS CLEAN-UP SYSTEMS. • HEAT EXCHANGERS LIFE IN CLOSED CYCLE SYSTEMS. • DURABLE BEARINGS AND SEALS NOT AVAILABLE AT ECONOMIC COSTS. • LARGE CAPITAL INVESTMENT. • HIGH PARTICULATE EXHAUST EMISSIONS. • DISPOSAL OF CALCIUM SULFATE WASTES.		
COAL LIQUEFACTION	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.7 x 10 ⁶ Btu/BARREL 207.0 x 10 ¹² Btu/YEAR OTHER PRODUCTS AMMONIA - 350 TONS/DAY SULFUR - 200-300 TONS/DAY	41.7 x 10 ³ TONS/DAY 15,231 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON) 34.7 x 10 ³ TONS/DAY 12,670 x 10 ³ TONS/YEAR (EASTERN COAL AT 24.7 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	1.261x10 ⁶ KWH/YR 3 MGD (STEAM AND H ₂ PRODUCTION) 19.6 MGD (EVAPORATIVE COOLING LOSSES) TOTAL 22.6 MGD	COBALT POLYBENEDUM 15 TONS/DAY NICKEL OXIDE CATALYST 0.6 TONS/DAY	FACILITY - 1,000 ACRES LAND DISTURBED 450 - 1,000 ACRES/YR (WEST) 1,900 ACRES/YR (EAST)	CONSTRUCTION - 7,000-8,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,400	\$ 1,000x10 ⁶	PRIMARY - 65%	1990 - 2010	(TONS/10 ¹² BTU INPUT) PARTICULATES 9 NOx 88 SOx 25 HC 2	HOD 10.5PPM COD 13.0PPM TSS 45.5PPM	ASH AND CHAR 3,000-4,000 TONS/DAY	• SOLIDS LIQUIDS SEPARATION. • RELIABILITY OF COMPONENTS FOR FEEDING SLURRIES. • IMPROVED CATALYSTS NEEDED. • CHARACTERIZATION OF POLLUTANTS AND SAFETY PROBLEMS IDENTIFICATION. • IMPACTS OF NEW MINES AND CONVERSION PLANTS ON LOCAL COMMUNITIES. • HIGH CAPITAL INVESTMENT.			
GAS AND OIL EXTRACTION	PRIMARY PRODUCT - CRUDE OIL .49 x 10 ³ BARRELS/DAY 178 x 10 ³ BARRELS/YEAR 5.6 x 10 ⁶ Btu/BARREL 1 x 10 ¹² Btu/YEAR OTHER PRODUCTS NATURAL GAS -	NONE	NONE	NONE	NONE	UNKNOWN	.008 MGD	SURFACTANTS POLYMERS AND OTHER CHEMICALS FOR TERTIARY RECOVERY (QUANTITY UNKNOWN)	TOTAL LAND IMPACT 5 ACRE - YR/10 ¹² BTU	UNKNOWN	\$ 0.3x10 ⁶ /10 ¹² BTU FOR AN OFFSHORE WELL (1973 COSTS)	OFFSHORE 30% ONSHORE 40% SECONDARY RECOVERY IMPROVEMENT-10-50% TERTIARY RECOVERY IMPROVEMENT-45-75%	PRESENT - 1985	(TONS/10 ¹² BTU CRUDE) PARTICULATES 0.002 NOx 0.004 SOx 0.003 HC 0.002 CO 1.5	ORGANICS 4 TONS/10 ¹² BTU TDS 3100 TONS/10 ¹² BTU	N/A	• ADDITIONAL DATA REQUIRED IN ENHANCED OIL RECOVERY. • RELIABILITY OF FRACTURING TECHNIQUES NEEDS TO BE IMPROVED. • INADEQUATE DATA BASE ON TAR SANDS. • PROBLEMS IN DRILLING DEEP FORMATIONS AND OFFSHORE AREAS. • HIGH CAPITAL INVESTMENT. • IMPACT OF FLUID INJECTION ON AQUIFERS NOT KNOWN. • DISPOSAL OF FLUIDS AND BRINE PRESENT A PROBLEM. • POLLUTION CONTROL TECHNOLOGY YET TO BE FULLY DEVELOPED.		
OIL SHALE	PRIMARY PRODUCT - SYNCRUDE 100 x 10 ³ BARRELS/DAY 36,500 x 10 ³ BARRELS/YEAR 5.8 x 10 ⁶ Btu/BARREL 211.7 x 10 ¹² Btu/YEAR OTHER PRODUCTS COKE - 1,600 TONS/DAY AMMONIA - 300 TONS/DAY SULFUR - 400 TONS/YEAR	1.7 x 10 ³ TONS/DAY 621 x 10 ³ TONS/YEAR (WESTERN COAL AT 20.1 x 10 ⁶ BTU/TON)	NONE	NONE	NONE	132x10 ³ TONS/DAY 48,180x10 ³ TONS/YR	1,489x10 ⁶ KWH/YR	15 MGD	VARIOUS CATALYSTS 1.8 TONS/DAY	FACILITY - 600 ACRES LAND DISTURBED - 150 ACRES/YR	CONSTRUCTION - 5,100-6,000 MAN YRS. (3-4 YR PERIOD) PEAK FORCE - 2,000 OPERATION - 1,500 - 1,800	\$ 1,000x10 ⁶	THERMAL - 5%	1985 - 1990	(TONS/10 ¹² BTU INPUT) PARTICULATES 17 NOx 124 SOx 69 HC 13	MINES 190PPM CARBONATES 520PPM CHLORIDES 330PPM CHROMATES 130PPM CYANIDES 50PPM ORGANIC ACIDS 1000PPM PHENOLS 60PPM	SPENT SHALE 108,000 TONS/DAY	• IN-SITU TECHNOLOGY NOT FULLY DEVELOPED. • SHALE CHARACTERISTICS NOT FULLY KNOWN. • OPTIMUM RETORT SIZE FOR MODIFIED IN-SITU YET TO BE ESTABLISHED. • DISPOSAL OF SPENT SHALE FROM ABOVE GROUND PROCESSES. • CLEAN-UP OF LARGE QUANTITIES OF GASEOUS EFFLUENTS. • WATER QUALITY PROBLEMS. • LARGE CAPITAL INVESTMENTS REQUIRED. • NEEDS GOVERNMENTAL INCENTIVE TO STIMULATE INDUSTRIAL DEVELOPMENT.	N/A

REGIONAL RESOURCES AND CHARACTERISTICS	REGIONAL CONSUMPTION (1974)		RESERVES - 13,601,200 x 10 ³ TONS		AUG. 1974 - 22.4 x 10 ⁶ CASKING PROPERTIES - NON-CASKING PRODUCTION - 0.613 x 10 ³ TONS TRANSPORT (10 ³ TONS)			RESERVES 13,651,135 x 10 ³ BARRELS		RESERVES 37,061,204 x 10 ⁶ Cu.Ft.			DISTRIBUTED 259,512 x 10 ⁶ KWH	DEPLETION RATE 3.0% CONSUMPTION (M.E.D.) 34,845	DOMESTIC MANUFACTURING 1,487 MINERALS 228 STEAM/ELECTRIC 32,510	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE METHODOLOGY	SEE 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Since 95 percent of the regional surface coal and 79 percent of the underground coal has a sulfur content of less than 1 percent, conventional coal fired boilers would be preferable to fluidized bed boilers for reasons of cost and simplicity.

Highways and railroads in the PAC region show a distinct north-south orientation, largely due to the region's mountainous topography. The main highways and railways connect Seattle, Portland, San Francisco, Los Angeles and San Diego. In addition, there are major east-west highways and rail lines extending across the Rocky Mountains, connecting Pacific Coast cities to inland cities. Alaska has only one secondary rail line connecting Fairbanks with Seward on the coast. In Washington, Oregon and California, the highway and rail systems are adequate to meet current and future energy development.

The PAC region has well-developed pipelines for the transportation of oil and gas between major metropolitan and industrial centers in the region. The Alaskan pipeline, which has begun to transport oil from the Northern Slope to Port Valdez, will make a significantly large contribution to petroleum supplies within the region.

Consuming Sectors

A. Industrial

Industrial development in the region is concentrated mainly in California, with some other industrial activity in the Seattle, Tacoma, Portland and Honolulu areas. Low Btu Gasification of Alaskan coal, or coal imported from another region, potentially could replace 0.9 quad of oil and natural gas consumption by the industrial sector, assuming regional coal transportation constraints are overcome.

B. Residential/Commercial

The R/C sector consumed 0.9 quad of natural gas and 0.3 quad of petroleum in 1974. California accounted for 87 percent of the natural gas and 46 percent of the petroleum consumed in this sector. High Btu Gasification of coal could reduce the R/C sector's dependence on natural gas, if the products were imported via natural gas pipelines from other regions or if coal transport systems were developed.

The demand for oil by the R/C sector as well as the transportation sector could be filled by liquids from Coal Liquefaction or Oil Shale technologies based in other regions. The combined demand for petroleum products within these two sectors is 2.8 quads.

C. Electric Utility

Hydroelectric energy amounts to 62 percent of the energy input to the EU sector. Since hydroelectric power is a renewable resource and has a weight of 0 in the Energy indices, the EU sector's Dependence Index value (44) and Consumption Index value (59) are very low (Table 39).

The electric utility sector also consumes a total of 0.8 quad of oil and gas. The use of coal by conventional means or later in Advanced Power Systems could replace this oil and natural gas, if regional and economic constraints can be overcome.

Conclusions

Once petroleum and natural gas production has matured in Alaska, all regional end-use requirements for these fuels can be met. In addition, large quantities of these fuels can be exported to other regions. Gas and Oil Extraction technologies should have important applications within this region.

IV. QUANTIFICATION OF ENERGY IMPACT SPECIFIC SCENARIOS

A. INTRODUCTION

The use of Energy Indices in quantifying national, regional and consuming sector dependence on scarce fuels has been described in Chapter II. In Chapter III Energy Indices were calculated for each census region and regional consumption sector. Also, the potential impact of advanced fossil energy technologies in reducing scarce fuel consumption was discussed.

In this chapter procedures for quantifying the impact of the introduction of an advanced fossil energy technology in particular regions will be described, and a series of distinct energy scenarios will be constructed. The flexibility of the method allows for a comparison and impact evaluation of alternative scenarios to determine which combination of technologies has the highest potential for reducing dependence on scarce fuels.

Seven scenarios covering a variety of possible energy situations or problems are discussed. Pertinent calculations are given for the first four scenarios and the results analyzed. The approach to solving the last three scenarios is described, but the calculations and analyses are left to the reader. An understanding of this chapter will allow the reader to construct other scenarios of interest, perform the required calculations using the 1974 data presented earlier in this report (or more recent data, if available), and assess the resulting energy impact.

B. SCENARIOS

I. INTRODUCTION OF LOW BTU GASIFICATION TECHNOLOGY

a. Description

Low Btu gas from coal could be substituted for a large fraction of the natural gas consumed in the industrial sector of the East North Central region. What would be the impact of this substitution on national, regional and industrial sector energy consumption?

b. Background

The East North Central Regional Analysis presented in Chapter III, Section 4, revealed that no significant regional constraints exist to the introduction of Low Btu Gasification technology to the ENC region. The quantity of industrial natural gas consumption that could be replaced is calculated as follows:

$$R = 1.6758 (0.8) \text{ quads}$$

where: R = industrial natural gas consumption replaced

1.6758 quads = natural gas consumption in the ENC industrial sector, obtained from Table 1

0.8 = Low Btu gas Technology Substitution Factor, obtained from Table 12

Using the above equation, R is calculated to be approximately 1.3 quads.

Savings of this amount could have a significant impact nationally in reducing dependence on natural gas. Data from the ENC Regional Fossil Energy Technology Matrix, Table 11, are used to structure the scenario.

c. Assumptions

As of January 1974, 11 low Btu gasification plants are assumed to be on-line and in full production. At the same time, coal production within the region has been increased to meet the requirements of these plants. The product, a low Btu gas rated at 175 Btu/cubic feet, is generated at a rate of 1429×10^6 cubic feet/day by each plant or 91.3×10^{12} Btu/year per plant (data from Table 11). The quantity of gas produced by the 11 plants results in 1.0043 quads of energy per year for ENC industrial use.

Each of the 11 plants consumes 6488×10^3 tons of coal per year, equivalent to an energy consumption of 0.1304 quads/plant (data from Table 11). All 11 plants consume 1.4344 quads of energy. The low Btu gas produced is used by industry as a substitute for natural gas in operations with process heat requirements. This assumed substitution of low Btu gas for natural gas would result in a reduction of regional natural gas imports, a corresponding decrease in the total national critical fuel, and a resulting decrease in its depletion rate. Note that increased coal use would result in higher net energy production and consumption.

The resulting changes in the 1974 ENC regional and U.S. total energy data bases are given in Tables 41 and 42, respectively.

Table 41

Scenario I Changes to 1974 Base Data
East North Central Region

(10¹² Btu)

	<u>Production</u>	<u>Consumption</u>	<u>Net Imports</u>
Coal	+1,434.4	+1,434.4	0
Natural Gas	0	-1,004.3	-1,004.3
Total	+1,434.4	+ 430.1	-1,004.3

Table 42

Scenario I Changes to 1974 Base Data
U.S. Total

(10¹² Btu)

	<u>Production</u>	<u>Consumption</u>	<u>Net Imports</u>
Coal	+1,434.4	+1,434.4	0
Natural Gas	-1,004.3	-1,004.3	0
Total	+ 430.3	+ 430.3	0

The weighting factors for each of the four different fuel types are now recalculated (see Chapter II, page 2-13 for original calculations). This recalculation is necessary because the weighting factors are based upon the depletion rates, Production of the four fuels reserves which have now changed in the scenario. Using production and reserve data from the Regional Totals row in Table 5, the new coal depletion rate is given by:

$$\text{New Coal Depletion Rate} = \frac{[610023 + 6488(11)]}{436725400} \times \frac{10^3 \text{ tons}}{10^3 \text{ tons}} = 0.00156$$

The new gas depletion rate is best calculated using the energy content of natural gas consumption replaced by the low Btu gas as follows:

$$\text{New Gas Depletion Rate} = \frac{(23.6958 - 1.0043) \text{ quads}}{259.9500 \text{ quads}} = 0.08729$$

The depletion rates for oil, 0.09351, and nuclear, 0.01801, are unchanged. The revised depletion rates are compared with the original depletion rates in Table 43.

Table 43

Scenario I Changes to 1974 Base
Data Depletion Rates

	<u>Base Case</u>	<u>Scenario I</u>
Coal	0.00140	0.00156
Oil	0.09351	0.09351
Gas	0.09109	0.03729
Nuclear	<u>0.01801</u>	<u>0.01801</u>
Totals	0.20401	0.20037

Normalizing the depletion rate results so that the sum of the base case fuel weighting factors will total 100, as before (see Chapter II, p. 2-13), yields the new fuel weighting factors shown in Table 44.

Table 44

Comparison of Fuel Weighting Factors

Coal	0.7	0.8
Oil	45.8	45.8
Natural Gas	44.7	42.8
Nuclear	<u>8.8</u>	<u>8.8</u>
Total	100.0	98.2

A comparison of these values reveals that the weighting factor for natural gas has dropped 1.9 points. Alternatively, while there has been a 9 percent increase in U.S. coal production, the coal weighting factor has increased by only 0.1 because of the large coal reserve base. The effect on the natural gas weighting factor is much more significant than that for coal, despite the fact that there is more Btu-equivalent energy produced and consumed in Scenario I than the Base Case. There is no effect on the weighting factors of oil and nuclear fuel since production is constant and the depletion rates remain the same.

Now the Energy Indices are recalculated using the new fuel weighting factors and revised production and consumption figures. The new Index values were normalized using the same normalization constants used to calculate the 1974 base case figures for comparison purposes. Defining equations for the various Energy Indices are presented and discussed in Chapter II, together with the appropriate normalization constants to use with each Index.

The revised ENC Industrial Sector Consumption Index is given by:

$$U_{ENC} = \frac{36(2.888)}{(68.6119+0.4301)} [0.8(1.4522+1.4344)+45.8(0.4201)+42.8(4.2110-1.0043)]$$

$$U_{ENC} = 75$$

The revised ENC Regional Consumption Index is given by:

$$U_{ENC} = \frac{9(2.888)}{(68.6119+0.4301)} [0.8(4.3631+1.4344)+45.8(4.8189)+42.8(4.2110-1.0043)]$$

$$U_{ENC} = 137$$

Revised Dependence Indices for the ENC Industrial Sector and ENC Region are calculated as follows:

$$D_{ENC} = \frac{2.888}{(3.5481+0.4301)} [0.8(1.4522+1.4344)+45.8(0.4201)+42.8(1.6758-1.0043)]$$

$$D_{ENC} = 36$$

$$D_{ENC} = \frac{2.888}{(13.7299+0.4301)} [0.8(4.3631+1.4344)+45.8(4.8189)+42.8(4.2110-1.0043)]$$

$$D_{ENC} = 74$$

The revised values for the ENC regional Indices are compared with the base case values in Table 45.

Table 45

Comparison of Index Values -
East North Central Region

<u>Index</u>	<u>Industrial Sector</u>		<u>Regional Total</u>	
	<u>Base Case</u>	<u>Scenario I</u>	<u>Base Case</u>	<u>Scenario I</u>
Consumption, U	144	75	157	137
Dependence, D	77	36	87	74

Revised Index values for the total U.S. are calculated in a similar manner. Base consumption data are obtained from the regional totals column in Table 5. Revised coal and gas consumption are obtained using the data in Table 42.

The expressions for the revised U.S. Total Consumption and Dependence Indices are identical:

$$U_{US} = D_{US} = \frac{2.888}{(68.6119+0.4301)} [0.8(12.3418+1.4344)+45.3(30.0062) + 42.8(21.9856-1.0043)+3.3(1.2018)]$$

$$U_{US} = D_{US} = 96$$

The revised U.S. Industrial Sector Consumption and Dependence Indices are calculated as follows:^{8/}

$$U_{US} = \frac{4(2.888)}{(63.6119+0.4301)} [0.8(3.6892+1.4344)+45.8(3.1907)+42.8(10.2836-1.0043)]$$

$$U_{US} = 92$$

$$D_{US} = \frac{2.888}{(17.1635+0.4301)} [0.8(3.6892+1.4344)+45.8(3.1907)-42.8(10.3826-1.0043)]$$

$$D_{US} = 90$$

The revised Total U.S. Indices are compared with the base case values in Table 46.

^{8/}The appropriate normalization constant used in calculating U.S. Industrial Sector Consumption Index is 4(2.888), since there are four Consuming Sectors.

Table 46
Comparison of Index Values -
U.S. Total

<u>Index</u>	<u>Industrial Sector</u>		<u>Regional Total</u>	
	<u>Base Case</u>	<u>Scenario I</u>	<u>Base Case</u>	<u>Scenario I</u>
U	102	92	100	96
D	102	90	100	96

d. Results and Analysis

The "Scenario I" Energy Index values for the ENC Industrial sector indicate that this sector's Dependence and Consumption Index values have been reduced to about 1/2 of the base case values. These changes occur even though the sector consumes an additional 0.4301 quad of energy with the introduction of the coal gasification technology. The reductions are due to the substitution of a plentiful fuel, coal, for a less abundant one, natural gas, and are a good measure of how effective such a change would be. Obviously, if a coal-based technology could have been implemented in 1974, as described above, the region's industrial sector would not have been so severely impacted by the natural gas shortage of 1976-1977.

The U.S. Total Energy Index values give an indication of the magnitude and the importance of the ENC Industrial sector in determining the nation's industry demand profile. The impact of replacing natural gas with coal in this one regional sector results in a 10 percent decrease in the critical use of rapidly depleting resources by the nation's industry. While changes in the index values for the region and total U.S. are not so great as in the industrial sector, the figures do reveal a definite impact on critical fuel consumption and dependence.

II. CONVERSION OF ELECTRIC UTILITIES FROM OIL AND GAS TO COAL

a. Description

Five electric utility plants in each of three regions have decided to convert from oil and gas to coal consumption. What would be the energy impact of the planned fuel substitution in the regions?

b. Background

The electric utilities in the U.S. had a total energy consumption of 20 quads in 1974 (see Table 4). Of this total, 7.0 quads were provided by oil and natural gas. It is desirable that the electric utility sector reduce its dependence on rapidly depleting oil and natural gas. If a change in consumption of the electric utility sector from an oil or gas base to a coal base is to take place, it is important to determine how this change would impact regional and electric utility sector energy consumption patterns.

c. Assumptions

Three regions were selected which have the highest electric utility sector Dependence Index values (see Table 10). They are the West South Central (120), New England (91), and Middle Atlantic (55) regions. The WSC electric utility sector is highly dependent on natural gas while the other two regions are more dependent on oil.

Five electric power plants which produce 1000 MW each are assumed to substitute coal for natural gas in the West South Central region. Also, five similar plants convert from oil to coal consumption in both the New England and Middle Atlantic regions. The average fossil electric plant conversion factor is 10,465 Btu/kWh. The total energy consumption for the five plants is calculated to be 458.4×10^{12} Btu/year or approximately 0.5 quad/year. Total energy consumption before and after conversion in the three regions is the same; only the fuel type consumed is different. It is assumed that necessary quantities of coal can be transported to the plant sites in each region.

It is also assumed that no change in overall U.S. energy production takes place. The increase in coal consumption and decreases in oil and gas consumption are reflected in changes in U.S. total exports or imports.^{9/} Power plant conversions are assumed to take place in 1974, so that the existing data base, fuel weighting factors, and index values previously calculated in this report can be used as bases to quantify the energy impact. New index values are calculated reflecting the increased coal consumption and decreased oil and gas consumption with the results shown below.

d. Results and Analysis

Changes in the Consumption and Dependence Indices for the three regions are illustrated in Table 47.

Table 47
Effect of Fuel Substitutions on Index Values

<u>Index</u>	<u>Region</u>	<u>Industrial Sector</u>		<u>Regional Total</u>	
		<u>Base Case</u>	<u>Scenario I</u>	<u>Base Case</u>	<u>Scenario I</u>
U	WSC	152	121	198	191
U	NE	35	4	45	37
U	MA	75	44	122	115
D	WSC	120	96	128	123
D	ME	91	10	121	100
D	MA	55	32	96	90

^{9/} An alternate assumption is possible. Changes in fuel consumption can be reflected in changes in fuel production. In this case revised production data are used to calculate revised fuel weighting factors and the new Indices are calculated in the manner described in Scenario I.

Table 48 shows changes in the index values for each region.

Table 48

Index Value Changes - Scenario II

<u>Index</u>	<u>Region</u>	<u>Electric Utility Sector</u>	<u>Regional Total</u>
U	WSC	- 31	- 7
U	NE	- 31	- 8
U	MA	- 31	- 7
D	WSC	- 24	- 5
D	NE	- 81	- 21
D	MA	- 23	- 6

The conversion of electric utility plants reduces the Consumption Index values by the same amount regardless of the region. This is due to the definition of the Consumption Index, as discussed below. The difference in impact occurs in the Dependence Index values. In the New England region the impact is extremely dramatic, with the EU Dependence Index value falling by 81 points, since the total capacity of EU Plants selected for conversion would virtually eliminate New England EU dependence on oil. This would have a significant effect on reducing dependence on oil in the whole region, as illustrated by the decrease of 21 in the New England regional Dependence Index value.

Since the initial Middle Atlantic EU sector dependence on oil ($D^{EU} = 55$) is not high because of the regional use of coal in that sector, the impact of the conversion scenario does not cause so dramatic a change in the figures as in New England. In fact, the MA change in Dependence Index values is similar to that of the West South Central region where the EU sector is highly dependent on natural gas. The reason for this is the similarity of total energy consumption in the two regions. Since the saving is similar and the total consumption is similar, the differences between index values are similar, even though the index values are very different.

The Consumption Index values change by the same amount because of the construction of the Index formula. (The change in the NE regional

Consumption Index value appears to be 1 unit different from the other regions but this is a result of rounding the values to whole numbers). Remember that the Consumption Index compares regional consumption with total national consumption. Therefore the same conversion from one type of fuel to another (the weighting factors for gas and oil are very similar) will have the same effect regardless of the region in which the change occurs. Since each regional energy mix is different, each region will start from a different base and will end up with different values. However, an equal change affecting equal quantities and the same (or similar) fuel weighting factors will result in a Consumption Index value change which is equal regardless of the regional base values.

III. INCREASE IN DIESEL-POWERED AUTOMOBILES

a. Description

Assess the impact on the regional and U.S. transportation sector consumption of energy, if 10 percent of all new cars sold in the United States from 1970 to 1974 were powered by diesel rather than gasoline engines.

b. Background

In 1974 the transportation sector in the U.S. consumed 18.4 quads of energy (Table 4), of which 9.2 quads, or about half, was attributable to passenger cars and taxis. Various conservation strategies have been and are being considered to reduce energy consumption in this vital sector. A diesel-driven U.S. automobile could produce a fuel economy of about 10 mpg over its gasoline-driven counterpart. U.S. automobile manufacturers are considering diesel-driven models and some are already on the market.

c. Assumptions

For the five-year period 1970 through 1974, 10 percent of all new foreign and domestic automobiles sold were diesel-driven. The average number of miles a car is driven in the first five years of its life is reflected in Table 49. (Data for this scenario are based on ERDA, Transportation Energy Conservation Data Book).

Table 49
Average Automobile Mileage -
First Five Years

<u>Year</u>	<u>Miles</u>
1	15,000
2	13,000
3	12,000
4	10,000
5	10,000

The mix of automobiles in this country is approximately 50 percent - 6 passenger, 25 percent - 5 passenger and 25 percent - 4 passenger cars. The average mileage increase with diesels for a mix of this type was found to be approximately 10 mpg. Based upon the number of autos sold, the number of miles driven, and the average savings of 10 mpg, the calculated cumulative savings for 1974 amounted to 2.295 quads of petroleum products.

The number of diesel-powered vehicles in each region (and the 2.295 quads of fuel savings) is distributed based on population in the nine census regions.

The reduction in petroleum consumption is reflected in an equivalent reduction of oil imports. Therefore, production is not affected and the fuel weighting factors remain the same.

d. Results and Analysis

The effect on the Energy Index values is shown in Table 50.

Table 50
Comparison of Index Values -
Nine Census Regions

	<u>Regional Consumption Index Values</u>		<u>Regional Dependence Index Values</u>		<u>Transportation Sector Consumption Index Values</u>	
	<u>Base Case</u>	<u>Scenario III</u>	<u>Base Case</u>	<u>Scenario III</u>	<u>Base Case</u>	<u>Scenario III</u>
NE	45	43	121	120	54	45
MA	122	115	96	95	165	137
SA	112	106	93	91	191	166
ENC	157	149	87	86	211	181
ESC	46	43	77	75	87	76
WNC	73	70	104	103	110	102
WSC	198	194	128	128 ^{10/}	169	154
M	46	44	93	92	70	63
P	101	95	100	99	170	149

^{10/}The WSC Regional Dependence Index decreases, but rounding off values to whole numbers masks this decrease. Relatively small effects might have been anticipated by noting that the transportation sector of the WSC region uses a smaller percentage of total regional energy than the transportation sector of any other region.

The changes in the regional index values resulting from the substitution of diesel fuel for gasoline are given in Table 51.

Table 51
Index Value Changes -
Nine Census Regions

	<u>Regional Consumption Index</u>	<u>Regional Dependence Index</u>	<u>Transportation Sector Consumption Index</u>
NE	- 2	- 1	- 9
MA	- 7	- 1	- 28
SA	- 6	- 2	- 25
ENC	- 8	- 1	- 30
ESC	- 3	- 2	- 11
WNC	- 3	- 1	- 8
WSC	- 4	0 ^{10/}	- 15
M	- 2	- 1	- 7
P	- 6	- 1	- 21

^{10/}The WSC Regional Dependence Index decreases, but rounding off values to whole numbers masks this decrease. Relatively small effects might have been anticipated by noting that the transportation sector of the WSC region uses a smaller percentage of total regional energy than the transportation sector of any other region.

Table 51 shows that the most significant changes in the consumption index values occur in the population centers of the West and East (i.e., Pacific, Middle Atlantic, South Atlantic and East North Central Regions). The Dependence Index for the West South Central region, where industry accounts for a relatively large portion of total energy consumption, is essentially unchanged.

In accordance with the assumptions of this scenario, 1974 oil imports would have decreased by 2.295 quads or 15 percent. Had the indicated conversions to diesel-powered vehicles been made, the impact of the oil embargo and subsequent price increases would have been partially alleviated.

IV. INDUSTRIAL ENERGY CONSERVATION REQUIRED TO PRODUCE A GIVEN DECREASE IN THE CONSUMPTION INDEX

a. Description

A region has a relatively high Consumption Index value in the industrial sector. The regional planning commission decides to reduce the Industrial Consumption Index value by 10 points in order to bring it more in line with the national average. What combinations of oil or gas consumption reductions are necessary to achieve this goal?

b. Background

Most scenarios examine a change in the mixture of fuel use and test its impact with Energy Index values. This scenario analyzes the reverse situation, using a desired change in an index value as a policy goal. The effect of a given reduction in index value is assessed. This scenario will help in understanding what a given change in index value means in terms of oil and gas consumption.

c. Assumptions

It is assumed that a region currently consumes a given amount of oil and gas in its industrial sector. If consumption of coal and nuclear fuel remains the same, a reduction in the Industrial Consumption Index value of 10 points will not result in a specific amount of oil and gas saved but in a series of combinations of different amounts of oil and gas that can be conserved. This relationship can be expressed either as a mathematical formula or a curve on a graph.

Initially, it will be assumed that fuel weighting factors remain the same. As a second alternative, it is assumed that production of oil has increased by 50 percent. This means that the weighting factor for oil will increase, but other fuel weighting factors will be unchanged.

d. Results and Analysis

The formula for the Consumption Index is:

$$U = n \sum_i W_i \left(\frac{C_R^i}{C_T} \right) \quad (1)$$

Where: U = Consumption Index for a regional industrial sector

n = a normalizational constant = 2.888(36)

i = coal, gas, oil, nuclear

W_i = weighting factor for each fuel

C_R^i = consumption of each fuel in the industrial sector

C_T = total national consumption of all fuels.

Equation (1) can also be written as:

$$U = \frac{n}{C_T} \sum_i W_i \left(C_R^i \right) \quad (2)$$

Multiplying both sides of equation (2) by $\left(\frac{C_T}{n} \right)$ and rearranging terms:

$$\frac{C_T U}{n} = W_C C_R^C + W_O C_R^O + W_G C_R^G + W_N C_R^N \quad (3)$$

$$W_O C_R^O + W_G C_R^G = \frac{C_T U}{n} - W_N C_R^N \quad (4)$$

In this scenario oil and gas consumption are allowed to vary while coal and nuclear consumption are constant. Hence the only variables in equation (4) are oil consumption, gas consumption and the Consumption Index.¹¹ The incremental form of equation (4) can be written:

¹¹ Rigorously, C_T is also a variable. Assuming that C_T is constant introduces less than 1 percent error in the calculation.

$$W_O \Delta C_R^O + W_G \Delta C_R^G = \frac{C_T}{n} \Delta U \quad (5)$$

Equation (5) expresses changes in oil and gas consumption (ΔC_R^O and ΔC_R^G) as a function of a change in the Consumption Index value (ΔU).

If the fuel weighting factors remain the same and 1974 consumption patterns are used:

$$C_T = 68,611.9 \times 10^{12} \text{ Btu}$$

$$n = 2.888(36) \quad (\text{for Industrial Sector Consumption Index})$$

$$W_O = 45.8$$

$$W_G = 44.7$$

$$\Delta U = -10$$

Substituting these values into equation (5):

$$45.8 \Delta C_R^O + 44.7 \Delta C_R^G = -6599.3 \quad (6)$$

This is a linear equation which will give the reduction in oil and gas consumption (in 10^{12} Btus) necessary to achieve a 10-point decline in the Industrial Consumption Index value for any region. To find the two intercepts, 0 can be substituted alternatively in the above formula for ΔC_R^O and ΔC_R^G .

ΔC_R^O	ΔC_R^G
0	-147.6
-144.1	0

Graphically, this is illustrated in Figure 9 as line AA. If oil consumption in the industrial sector were to remain the same, a reduction of 147.6×10^{12} Btus of natural gas would be required for a 10-point reduction in the Industrial Consumption Index value. Alternatively, if there was no reduction in natural gas usage, a decrease of 144.1×10^{12} Btus of oil would achieve the 10-point reduction. Or, for example, a combination of -40×10^{12} Btus of oil and -106.7×10^{12} Btus of gas would result in an equivalent reduction. Since the weighting factors for oil and gas are very similar, the intercepts and the trade-offs between oil and gas reductions to achieve the 10-point reduction are similar.

FIGURE _
 REDUCTIONS IN OIL AND GAS CONSUMPTION NECESSARY TO ACHIEVE
 A 10 POINT REDUCTION IN THE INDUSTRIAL CONSUMPTION INDEX VALUE

The fuel weighting factors can be altered to reflect changes in fuel production rates. As an example, an increase in production of oil by 50 percent is assumed. The weighting factor for oil, therefore, is increased by 50 percent¹² from 45.8 to 68.7 as a result of the production increase, while the other fuel weighting factors remain the same because neither production nor reserves of the other fuels have been altered. Substituting the revised weighting factors into equation (5) gives:

$$68.7 \Delta C_R^O + 44.7 \Delta C_R^G = -6599.3 \quad (7)$$

The new intercepts are as follows:

ΔC_R^O	ΔC_R^G
0	-147.6
-96.1	0

The line AB in Table 35 is the graphical representation of equation (7). It can be concluded that, if the weighting factor for one fuel (in this case, oil) increases while the other fuel weighting factors remain the same, less oil needs to be saved in order to reduce the index value by 10 points. In this specific case, 96.1×10^{12} btus of oil would need to be conserved if no natural gas were saved. In other words, each unit of oil consumption has a greater impact because the weighting factor for this fuel has been increased.

¹²Recall that the fuel weighting factors are determined by depletion rates, i.e., production/reserves.

To illustrate how this analysis works in specific regions, there follows an example using 1974 consumption patterns and the original fuel weighting factors. The 1974 oil and gas consumption in the industrial sector of the regions selected for analysis are presented in Table 52.

Table 52
Industrial Sector Energy Consumption -
Base Case - 1974
(10¹² Btu)

<u>Region</u>	<u>Oil</u>	<u>Gas</u>
NE	181.3	53.2
SA	444.8	680.9
ESC	107.1	547.2

Assuming that a 10-point reduction is desired in the Industrial Consumption Index value, the line AA in Table 35 indicates which combinations of oil and gas conservation measures would achieve the desired result. If only gas were conserved in the NE region or only oil conserved in the ESC region, it is obvious that achieving a 10-point reduction in the Industrial sector regional index values would be impossible. However, combinations of oil and gas reductions would permit the goal to be achieved.

Using equation (6), Table 53 shows some combinations of reductions which would reduce the industrial sector Consumption Index value by 10 points in each region.

Table 53.

Sample Reductions in Oil and Gas Consumption For a 10-Point
Reduction in Industrial Sector Consumption Index Value

(10^{12} Btu)

Region	Oil	Gas
NE	-125.6	- 20.0
SA	- 44.8	-101.7
ESC	- 50.0	- 96.4

These sample reductions are applied to the Base Case Consumption data with the results indicated in Table 54.

Table 54.

Revised Industrial Sector Energy Consumption To Achieve a 10-Point
Reduction in Industrial Sector Consumption Index Value

Region	Oil	Gas
NE	56.7	33.2
SA	400.0	579.2
ESC	57.1	450.8

V. SUBSTITUTION OF COAL FOR OIL AND GAS IN MANUFACTURING INDUSTRIES

a. Description

The manufacturing industries substantially increase the use of coal with an equivalent decrease in oil and natural gas use for heat and power applications. Analyze the national and regional impact of the fuel substitutions.

b. Background

The U.S. industrial sector consumed about 20.1 quads of energy in 1974 (Table 4). This sector was 18 percent dependent on coal, 26 percent on oil, 44 percent on natural gas and 12 percent on electricity. Of the total 20.1 quads, about 78 percent was used for process heat, steam and power requirements. The National Energy Plan encourages industry to shift to the use of more abundant coal, especially for heat and power applications. The impact of such changes on the national consumption of critical oil and gas is to be determined.

As this study was limited to 1974 data, the approach will assume charges to the 1974 data base. However, the same analytical methods could be applied if projected patterns of industrial fuel use, new industrial boiler orders and forecasted U.S. and regional consumption data were available.

c. Assumptions

There is assumed to be 20 percent reduction in the use of oil and natural gas (for heat and power) with an equivalent (Btu) increase in consumption of coal by the industrial sector. This reduced consumption of oil is reflected in reduced oil imports rather than reduced domestic production. However, the reduced consumption of natural gas is reflected in lower natural gas production. Increased production and transportation of coal is assumed to be possible.

d. Approach

Revised fuel weighting factors are calculated, reflecting the decreased production of natural gas and the increased production of coal. Use of oil and gas for heat and power purposes would be reduced by 20 percent in each region,^{13/} and coal consumption would be increased by a like amount. New index values are calculated and the values compared with base case values.

It is expected that industrial sectors in regions which are highly dependent on gas and oil would experience the most dramatic index value reductions.

^{13/}Unequal reductions in various regions can also be assumed, as required.

VI. RECONVERSION OF ELECTRIC POWER PLANTS THAT SWITCHED TO OIL AND GAS
IN THE PAST 10 YEARS

a. Description

Because of environmental considerations, many electric utilities have switched from coal to cleaner burning oil and natural gas in past years. If these plants are reconverted to coal, what would be the energy impact?

b. Background

A number of electric power plants, particularly west of the Mississippi, converted from use of coal, a relatively abundant fuel, to oil or gas for environmental reasons. These conversions obviated the need for large amounts of capital investment in particulate and SO₂ removal equipment by substituting, at the time, relatively cheap oil or gas. Since 1974, costs of oil and gas have increased considerably. Capital investment necessary to reconvert to coal should be weighed against increases in the cost of oil and gas. This scenario will address the energy impact in the utility sector if these plants are reconverted, or equivalently, had they not originally been converted to oil or gas.

c. Assumptions

Using historical data, assume that all electric power plants that converted from coal to oil or gas in the past 10 years are reconverted to coal in 1974. Also, assume that coal production is increased, gas production is decreased and oil imports are decreased as required.

d. Approach

Calculate revised fuel weighting factors for coal and gas, reflecting production changes. The oil weighting factor is unchanged. Using historical data, replace affected electric utility consumption of oil and gas with coal. Recalculate the electric utility sector, regional and national consumption index values and compare with base case values. °

VII. STEAM-ELECTRIC GENERATING PLANTS PLANNED OR UNDER CONSTRUCTION
1975-1985

a. Description

Steam electric plants expected to be built by 1985 include nuclear and hydro-powered plants as well as fossil fuel plants fired by coal, oil and natural gas.

1. Compare regional electric utility sectors in 1974 with those planned for 1985.
2. If the plans were modified so that coal plants were substituted for oil and gas plants through 1985, compare the electric utility sector of 1974 with an all coal, nuclear and hydro option in 1985.

b. Background

In 1974 the electric utility sector was 43 percent dependent on coal, 17 percent on oil, 18 percent on natural gas, 16 percent on hydro and 6 percent on nuclear (Table 4). The total gross electric utility sector energy consumption amounted to 20.0 quads in 1974 and is projected at about 33.7 quads in 1985. The plants included coal, oil or gas fired steam-electric, nuclear, hydro, including pumped storage, geothermal, gas turbine and internal combustion. Information that the utilities file with the Federal Energy Regulatory Commission indicates that about 200 fossil energy plants producing 160,000 MW are planned through 1985, of which 138 plants are to use coal. It is desirable that the electric utility sector reduce its dependence on scarce oil and natural gas by increasing its use of coal and other forms of energy for producing electric power.

c. Assumptions

The utility plants and capacities planned through 1985 are determined from the utility filings with the Federal Energy Regulatory Commission. Average plant conversion efficiencies will be assumed the same as in 1974. Also, it is assumed that the plants will be operated at rated capacity.

d. Approach

Projections of fuel production and reserve data in 1985 would be obtained from existing literature so that new fuel weighting factors could be calculated. Projected electric utility sector Index values would be calculated and compared with 1974 values. After plant data is altered for part B of the scenario, Index values are recalculated. Finally, an analysis and comparison of the these values is made.

V. SUMMARY AND RECOMMENDATIONS

A. SUMMARY

An energy supply/demand profile has been prepared for each state. The profile contains 1974 data on fossil energy reserves, processing, production, consumption and net foreign and domestic imports and exports for each state. Similar data for each of nine census regions and a summary for the U.S. are also included.

Four Energy Indices have been defined which summarize a region's energy consumption and demand characteristics. The indices are defined to include the effect of consumption of relatively scarce fuels (oil and gas) versus plentiful fuels (coal). The fuel weighting factors incorporated into the indices are based upon national depletion rates, i.e. $\frac{\text{production}}{\text{reserves}}$. The higher the index value, the more critically dependent the particular region and sector are on scarce fossil energy resources.

Energy Indices were calculated for 1974 energy use patterns on a census region basis in this study. The results of these calculations are used to identify particular regional energy consuming sectors with great dependence on scarce oil and gas fuels. The Energy Index technique, however, is not restricted to this data base. It can be applied geographically by region, state, or sub-state area. Current, past, or projected energy data can be used. Analysis can likewise be carried out by industry groups within the industrial sector. Other energy technologies and fuel types can be used, including solar and geothermal energy. The principal limitation on the application of the technique is availability of a data base.

The Energy Index technique is particularly useful in quantifying the local, regional and national impact of fuel substitutions or energy conservation programs. This is accomplished by calculating revised Index values based upon the particular fuel substitution or conservation measures and comparing the new values with the old. Several "what if" fuel substitution and energy conversion scenarios have been formulated and the impacts on national, regional and consuming sector's energy posture evaluated.

Seven advanced fossil energy technologies have been analyzed with respect to capital investment and input resource requirements, primary products and by-products, and problems and constraints associated with implementation of the technologies. The technologies are: High Btu Gasification, Low Btu Gasification, Direct Combustion, Advanced Power Systems, Coal Liquefaction, Gas and Oil Extraction and Oil Shale. A Fossil Energy Technology matrix has been prepared for each census region for comparing resources available within the region to those required by the technologies. As a result of such comparisons a technology is determined to be either applicable within the region, or applicable with some regional constraints, or nonapplicable.

The potential energy impacts of the fossil energy technologies can be assessed to two ways. First, a specified number of plants or facilities can be assumed to be introduced within a region and the resulting impact calculated. Secondly, the maximum impact of a technology can be assessed by noting that there is a maximum amount of oil and gas consumption which can be replaced with the technology depending upon consuming sector and fuel characteristics. In this case the maximum impact is calculated based upon critical fuel substitution to the maximum extent.

A major objective of this program was to develop and demonstrate an easily understood technique, based on index numbers, that could be used to determine the relative importance of energy supply/demand regions and sectors for a variety of scenarios. The approach developed appears to meet this objective. It is based on simple relationships which are well known to the decision maker. It is particularly understandable because it is modular and does not attempt to combine all elements in a set of equations which might obscure the process. Because it is modular, improvements to a part of the technique can be made without disturbing other parts. The technique can be used to estimate the impact of existing and proposed policy.

B. RECOMMENDATIONS

1. State Analysis

It is recommended that the technique be applied on a state-by-state basis since this would permit a more detailed analysis. Furthermore, the

comparison of resources and characteristics with fossil technologies was limited because much of the data was available on a state basis and could not properly be averaged into a regional summary. (For example, environmental standards vary from state to state.)

Sometimes the analysis of a region was distorted by the variations in energy resources among the states which constitute the region. For example, the Carolinas and West Virginia fall within the same region but have very different energy profiles. In this way, the energy needs of a state without fossil energy reserves can be obscured by regional totals. Regional reserves in the Middle Atlantic region appear substantial, but Pennsylvania is the only state in the region with appreciable amounts of fossil reserves, and most of this is in the form of coal. An analysis was performed in an attempt to re-regionalize the states on the basis of energy characteristics, but no single regionalization was found to be satisfactory. Hence, the recommendation is made to apply the technique to each state individually. Such results would also be more useful to the states for energy planning.

2. Other Advanced Technologies

It is recommended that non-fossil energy technologies also be analyzed. Solar and conservation technologies, for example, should be added to the fossil technologies so that more broadly based energy policy analysis can be accomplished.

3. Use of Forecast Energy Data

Available 1974 data were used in this program to develop and test the technique. It is recommended that the technique be applied to a base case forecast of energy supply and demand to provide more realism in policy analysis.

CHAPTER VI

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