Chapter II

ENERGY AND THE ROLE OF COAL

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TABLES

FIGURES

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ENERGY AND THE ROLE OF COAL

Coal is expected to rapidly become more important in the Nation's energy system. Its abundance relative to domestic reserves of oil and gas should preclude the steep price increases that may be in store for oil and gas as their production becomes more expensive, and most observers conclude that our present heavy dependence on foreign oil is a grave political and economic liability.

Many of the functions served by the energy of oil and gas could also be served by coal, as they were in the past. Others, however, such as residential heating and transportation, seem less appropriate for coal to serve unless the coal is first converted to a more convenient form. It is necessary to examine energy demand in general, and the various sectors of energy consumption in particular, to determine the degree to which coal can rejoin the energy system and how. This chapter describes the factors that determine energy and coal demand Three energy scenarios are presented to demonstrate a range of possible coal growth requirements. These scenarios reflect the range of most current predictions, though recent projections have tended to be toward the lower end of this range. Thus the high development scenario serves to indicate the probable upper limit on the amount of coal that will be needed. If the actual level is lower than the low development scenario, both the challenge of meeting demand and the resulting impacts will be reduced. The coal production and combustion elements of the scenarios are described in detail to set the stage for the following chapters.

KEY FACTORS AFFECTING ENERGY DEMAND

Three primary factors are ultimately responsible for determining future energy use: population, economic activity as indicated by the gross national product (GNP), and efficiency of energy use. Each factor is a complicated function of subfactors, which are often interrelated. Appendix I in volume II amplifies this abbreviated analysis.

People are the final consumers of the goods and services that use energy. The higher the population, the more energy will be needed. Changes in population growth are determined by fertility, death, and immigration rates. Estimates of the former range from 1.7 to 2.1 births per woman over her lifetime (1.8 in 1975), but the effects on energy consumption will not be great before 2000. The death rate is not expected to change significantly by 2000. Hence immigration is the least certain factor. Population is expected to be between 246 million and 260 mill ion by 2000, an increase of 13 to 20 percent from the present 217 million. Of more immediate concern are the demographic shifts within the total population. The labor force will grow considerably faster than the population as a whole. The shift in the median age that this implies suggests not only that GNP will increase as described below, but that households and drivers, both major energy-consuming groups, will increase faster than population. Changes in tastes, lifestyles, and habits, perhaps engendered by rising prices, can also affect energy demand, but such shifts cannot be confidently predicted.

GNP is a measure of overall economic activity, most of which consumes energy. A close relationship has been observed in the past between GNP and energy consumption. The recent charges in this relationship are discussed in the next paragraph. GNP obviously depends in part on the population size and the labor force in particular. The number of persons in the labor force age group (16 to 65) can be predicted quite accurately to the year 2000. The number of persons actually working depends on the labor participation rate and the unem-

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ployment rate. The former is expected to continue its upward trend, reflecting the increased participation of women. Unemployment is expected to drop below 5 percent for most of the rest of the century. The positive effect of a large population and a higher rate of participation in the labor force is partially offset by the expected continuation of the long-term decline in work hours; average hours worked per week dropped from *40.0* in 1948 to 37.1 in 1973. The final element in estimating future GNP is labor productivity, the measure of output per worker, per hour worked. The replacement of manpower with capital, materials, knowledge, and energy has been the historic means of increasing productivity. It now appears that industry is finding a more attractive return on its capital when it restructures this equation to reduce the use of energy. This is one of several factors that have led to a long-term decline in the rate of growth of labor productivity. If this rate continues to decline, a very low-growth economy with lower energy needs than this report assumes will emerge. Recent concern has led to tax law changes, indicating that a national commitment exists to reverse the decline, which is the assumption of this analysis. All these factors combine to yield estimates of G N P in 2000 of $3,300 billion to $3,600 billion (constant dollars) compared to $1,516 billion in 1975. This increase of 120 to 140 percent will about double real, per capita income.

Energy efficiency relates the performance of a given task or process to the quantity of energy required. Efficiency (or the conservation measures implemented to enhance it) is not to be confused with constraint, which implies less consumption of the goods or services involved. Energy efficiency rises largely in response to economic pressures — fuel prices in particular— but also to tax benefits and other policies. History provides little help in estimating the response to energy price increases, as the cost of fuel was stable or slowly declining in real terms throughout the century. Until 1973 there was little incentive to design for energy efficiency and almost none to change an existing practice. The situation is quite different now, and decisions based on cost estimates will result in rising energy efficiency. There will be exceptions. As resources become scarcer, more energy will be required to produce them, and as energy conversions such as electricity and synthetic fuels assume a larger role, efficiency will be adversely affected. Nevertheless, recent economic and energy data imply that energy and GNP have been largely decoupled and a substantially different ratio will be established. Measuring this change is much more difficult than measuring the previous factors. Conservation will be a function of fuel prices, which will depend in part on factors such as domestic oil and gas reserves, foreign and domestic policy decisions, and technology developments. Thus the uncertainty in projecting future energy efficiencies largely accounts for the wide range in the scenarios to follow.

DEMAND SCENARIOS

Forecasting energy demand is a highly uncertain art. As described in the previous section, there are too many important variables that can only be speculatively quantified. Depending on assumptions, modelers can produce scenarios for 2000 predicting anywhere from 60 to 190 Quads[1] (73.1 Quads in 1975). Both extremes are highly improbable. Most forecasts fall between 100 and 150 Quads. Rather than selecting existing scenarios or creating more, the following analysis simply assumes energy consumption levels in 2000 of 100, 125, and 150 Quads and then determines the circumstances that would be consistent with arriving at each level and the patterns in which these aggregate levels would be distributed.

The objective of these energy demand scenarios is to determine the impact of a given

[1] A Quad is short for quadrllion Btu

level of aggregate energy demand on coal consumption. Aggregate demand is the sum of residential/commercial, industrial, and transportation demand, Most energy used in residences and commercial establishments is for heating and cooling. Oil and gas are the primary fuels for direct heating and electricity for cooling. The use of electricity for heating is increasing rapidly. The transportation sector is a major consumer of liquid fossil fuels. Industry and electric utilities, which use large quantities of energy to produce steam, are the prime candidates for the substitution of coal for oil and gas.

The 100-Quad demand scenario is a slow-growth scenario. An assumed fertility rate of 1.7 births per woman marks the leveling off of a long-term decline in U.S. fertility, and with moderate immigration results in a projected population of 246 million in the year 2000. This modest increase in population is accompanied by an equally modest average rate of GNP growth: 3.8 percent between 1975-85, and 2.8 percent between 1985-2000.

A key assumption in the 100-Quad scenario is a major increase in the price of oil and gas relative to coal because of a disappointing discovery rate. The price of oil is expected to increase to $25/bbl in 1975 dollars by the year 2000, while natural gas increases to $4.30/1 ,000 ft' at the wellhead. These dramatic price increases reflect increased scarcity and deregulation of oil and gas. Long-term contracts and a competitive industry will prevent coal prices from rising as rapidly: from $1 7.50/ton in 1975 to $28.88/ton in 2000. Accordingly, oil prices increase by a factor of 2.4, gas prices by a factor of 10, and coal prices by a factor of 1.65. The price of energy to the consumer will not increase as much because other determinants of retail energy prices (refining costs, distribution costs, etc.) will not rise at the same rate as fuel costs. As a result, electric power increases from 2.7 cents/kWh to only 4.5 cents/kWh in 2000. The basis for these increases is discussed in the *Supp/y Alternatives* section of this chapter and in appendix I of volume II.

These increases in absolute energy prices lead to major efforts to implement energy-saving technology, resulting in increased energy efficiency. In industry a 30-percent increase in energy efficiency is assumed. Industrial use of petrochemical feedstocks is also forecast to grow at a much slower rate as a result of high prices. In the transportation sector auto efficiency increases from 14 miles per gallon (mpg) in 1975 to 27 mpg in 2000, small trucks and vans increase in efficiency from 11 to 18 mpg: heavy trucks, planes, and ships experience a 20-percent increase in efficiency. In the residential/commercial sector it is assumed that 2 percent of old homes (pre-1975) and commercial structures are retrofitted with insulation each year, and 10 percent are fitted with heat pumps by 2000, All new homes and commercial structures are insulated, and 25 percent of these are equipped with heat pumps.

The breakdown of sectoral energy demand resulting from these assumptions is shown in table 1. The increase in household/commercial energy demand greatly exceeds population growth because of demographic shifts and a substantial increase in per capita use; however, it is much less than the assumed increase in the number of households and in commercial footage, implying increased efficiency. The significant increase in industrial energy use is partially explained by the corresponding growth in GNP, 120 percent between 1975 and 2000. Energy consumption grows slower than GNP for two reasons: first, the achievement of increased energy efficiency already cited; and second, a substantial shift in the composition of industrial production away from petrochemical products. Transportation energy demand rises slightly faster than population, reflecting the increased gas mileage of automobiles and offsetting increases in mileage driven per capita, air travel, etc.

The 125-Quad scenario implies a more liberal supply system but a less successful conservation effort. Thus energy prices are the same as in the 100-Quad scenario. The key demographic and economic assumptions in the 125-Quad scenario are essentially the same as in the 100-Quad case, but the Nation has not been as successful in implementing energy-efficient technology, nor has there been a sub-

Table 1.—Energy Demand Scenarios, Year 2000, and Their Determinants

Demand scenarios/primary assumptions	Residential/commercial Wads	% change	Statistics	Industry Quads	% change	Statistics	Transportation Quads	% change	Statistics
1975 73.1 Quads	257		#of homes' 72x 10* Commercial ftft² 252 x 10⁹	28.5		High energy consumption In petrochemicals	18.8		Autos 104 x 10⁴ MPG 14 MPG (trucks) 11
2000 Scenario A 100 Quads Fertility rate 17 Hours worked 198 x 10* Labor productivity growth 1970-80 1 8% annual 1980.85 2 2% annual 1985.2000.2 6% annual GNP growth per year 1975.85: 3 8% 1985-2000: 2 80/0	335	30 "/0	#of homes 102 x 10⁶ (+ 420/.) Old (pre- '75) 434 x 10⁶ New 586 x 10⁶ Commercial ftft² 946 x 10⁸(+ 2750/.) Old 152 x 10' New 294 x 10⁹ Retrofit rate Old 20/. insulated/year 10% heat pumps New all Insulated 25% heat pumps	44.3	70.4%	Shift composition away from petrochemicals 30 "/0 Increase in efficiency	222	18.1 %	Autos. 120 x 10" (15"/0) MPG 27 MPG (trucks) 18 20°/0 increase m efficiency
2000 Scenario B 125 Quads Fertility rate 1.9 f-fours worked 200 x 10⁹ Labor productivity growth: (Same as Scenario A) GNP growth per year: (Same as Scenario A)	444	72%	#of homes same as Scenario A Commercial ft same as Scenario A Retrofit rate Old 1% insulated/year New 10°/0 heat pumps	525	101 %	Shift composition away from petrochemicals 20% increase in efficiency	281	49.5%	Autos. 152 x I@ (46%) MPG 27 MPG (trucks) 18 10% increase In efficiency
2000 Scenario C 150 Quads Fertility Rate 19 Immigration + 750,000 f-fours worked. 203 x 10⁹ Labor productivity growth 1975-80 2 0% annual 1960-85 2 40/. annual 1985-2000 2 80/. annual GNP growth per year: 1975-85 40/0 1985-2000 3%	542	111%		64.3	147 "/0		315	67 5%	Autos: 170 x 10' (630/')

No change in efficiency factors increased consumption of energy is the result of lowered energy prices occasioned by increased availability of liquid fuels and natural gas

stantial shift in industrial production away from petrochemicals. ' The difference in energy consumption in the two cases is primarily attributable to the differences assumed in energy efficiency. In industry the increase in energy efficiency is 20 percent instead of 30 percent. In transportation, the efficiency increase for heavy trucks, planes, and ships is 10 percent instead of 20 percent. In the residential/commercial sector the retrofit rate of insulation into old homes is 1 percent instead of 2 percent, and only 10 percent of new homes and commercial structures have heat pumps. The only other significant departure from the 100-Quad scenario is the number of automobiles–l 52 million instead of 120 million.

The 150-Quad scenario may be characterized as a high-growth, cheap-oil case. It assumes no improvements in energy efficiency. Energy fuel prices are much lower than in the other two cases. Oil is only $12.48/bbl, natural gas is only $2.25/1 ,000 ft³, and the price of coal and electricity is unchanged from 1975 levels of $1 7.50/ton and 2.7 cents/kWh respectively. Oil and gas are priced much more favorably in relation to coal and electricity than in the low- and medium-demand scenarios. The automobile population in this high-growth scenario is 170 million, much greater than in the previous scenarios.

Implications

The greatest growth in these scenarios is in the use of electricity by the industrial and residential/commercial sectors. All these incorporate lower growth in electricity than the historical average, but this growth rate has been declining since about 1966 to the present 3.4 percent that is envisioned for the 100-Quad scenario. The direct use of energy by industry has grown slowly over the last three decades. Industrial consumption totaled 18.8 Quads in 1977, only 47 percent higher than in 1947 and actually lower than in 1968.[3] A resumption of

[2]The population assumptions are slightly higher for this scenario — an estimated *254* million based on a fertility rate of 1 *9;* however, no affect is assumed on GNP, which is the same as i n the 100-Quad case.

[3]*Annual Report to Congress, 1977,* Department of Energy, Energy Information Administration.

rapid growth by industry is unlikely. Opportunities for the substitution of coal for oil and gas are limited and is discussed later in this chapter under the section, *Projections of Coal Production and Use.*

In the commercial sector, total demand has increased in al l three scenarios, but the 100-Quad scenario actually lowers direct use of energy. Electric power and synthetic fuels are clearly substitutable for oil and gas in this sector. The extent to which direct combustion of coal is substitutable hinges upon a number of factors, which are examined subsequently. The transportation sector, for the most part, depends on liquid fuels, hence the direct combustion of coal and electric power is limited as a substitute. Demand growth in this sector means demand growth for oil, natural or synthetic. The greater number of automobiles in the higher scenarios implies a continuing development of outlying suburbs, less mass transit, and increased driving for recreation.

A word should be said about how these demand scenarios compare with other studies. The Department of Energy (DOE) conducted its Market Oriented Program Planning Study (MOPPS) in 1977. Total primary energy demand estimated by MOPPS in the year 2000 is 117.25 Quads, which is bracketed by the 100- and 150-Quad scenarios. The breakdown of the MOPPS estimate by sector is 36 Quads for the household/commercial sector, 20.8 Quads for transportation, 56.9 Quads for industry, and 3.5 Quads for metallurgical coal exports.

Comparing MOPPS to the 100-Quad scenario, the most significant difference is in the industrial sector, where the MOPPS estimate exceeds the 100-Quad scenario by 12.5 Quads. The MOPPS scenario projects increased use of gas and oil as petrochemical feedstocks, and the overall increase in energy efficiency is presumably lower than that assumed for the 100-Quad case. The MOPPS industrial energy demand more closely approximates the *52.5* Quads estimated in the 125-Quad scenario, where overall industrial energy efficiency increases are one-third less than in the 100-Quad case, and where petrochemical feedstocks continue at pre-1975 rates of use. The significant source of difference between the 125-Quad scenario and MOPPS is in the household/commercial sector, 44.4 Quads compared to 36 Quads in MOPPS. This relatively large difference is accounted for by greater implementation of energy-saving technology in the MOPPS scenario.

The Energy Information Administration of DOE, in its Annual Report to Congress for 1977, projects a domestic consumption of about 100 to 110 Quads in 1990, with a sectoral distribution similar to this report's 100-Quad scenario. The Electric Power Research Institute (EPRI), in their report "Supply 77" of May 1978 uses a reference case for 2000 of 159 Quads and compares it to scenarios of 146 and 196 Quads. EPRI clearly expects a more favorable fuel supply situation, less public and governmental intervention, and lower price elasticities than this report considers probable. At the other extreme, the Committee on Nuclear and Alternative Energy Systems considered levels of energy consumption as low as 58 Quads and up to 180 Quads in 2010.[4]

In creating the three scenarios, various assumptions have been stipulated regarding key factors and relationships. Little has been said about the implications of a given scenario for lifestyles. The way people live and their attitudes have a great deal to do with their willingness to accept constraints on their behavior that might be implied by energy resource constraints and high prices. Whether consumers would resist conservation policies is a matter of speculation.

Americans have traditionally duly complied with requirements associated with emergency situations, but indefinite compliance is a different matter. Most people are economically rational, however, and if it is apparent that price increases are not contrived and are being applied fairly, they will adjust their patterns of consumption appropriately.

The historical growth rate in per capita energy consumption since 1950 has been 1.4 percent annually. The scenarios discussed here result from 0.9-, 1 .7-, and 2.3-percent increases.

[4]U.S. Energy Demand Some Low Energy Futures, " 5cience, Apr. 14,1978

Thus even 125 Quads implies an acceleration of per capita energy consumption growth. Given expectations regarding increased energy efficiency and higher fuel prices, there is no reason to assume that rational Americans cannot adjust to a reduced rate of increase in energy use. There is no basis for concluding that the lower per capita growth in energy use will result in deprivation. Hence low energy-growth scenarios cannot automatically be rejected as contrary to the demands of the American people. On the other hand, if 150 Quads are available at sufficiently low prices, ways will be found to use them, and it is incumbent on low energy-growth advocates to suggest how consumers will be spending their doubled real income, if not for energy-consuming goods and services, or whether in fact economic growth should be dropped as a national goal.

SUPPLY ALTERNATIVES

Historical y, energy supply has risen to meet demand wi thout major increases in prices, largely because of the Nation's vast resources and the increasing efficiency of production. The situation is quite different now. Few if any analysts expect the Nation's production rates of oil and gas to double at any price. Total exhaustion is not a near-term concern, but resource depletion is sufficiently advanced that major new discoveries are noticeably harder to make, and new production is significantly more expensive. As oil and gas currently supply 75 percent of national energy demand, an indefinite continuation of past trends is not an option for the future. These expectations are reflected in the price assumptions for the 100- and 125-Quad scenarios. The 150-Quad scenario incorporates much lower prices for natural gas and oil on the assumption of major new discoveries.

The energy sources considered here are oil, gas, coal, nuclear, solar, and geothermal. Hydropower is not expected to increase significantly because of the lack of economic sites not subject to significant environmental degradation. Each energy source presents a different set of characteristics that are valued differently by the various users. The most important characteristics are price (including transportation), convenience, facility cost, cleanliness, and reliability of supply.

100-Quad Scenario

The essence of the 100-Quad scenario is the sharply higher price of oil and gas caused by resource constraints. The same high price structure could result from a high fuel tax policy, but such a policy is improbable unless impending resource constraints are widely perceived to be real. The higher prices keep U.S. oil and gas production close to current levels through enhanced recovery and exploitation of less attractive sites, such as Alaskan, offshore, and marginal fields. Oil imports are expected to drop in response to policies aimed at that end. Coal production is expected to more than double and actually become the most important fuel. Nuclear power increases rapidly but more modestly than most recent projections. Solar energy increases at a very rapid rate, but the time frame is too short to do much more than lay a significant base for the 21st century. New technologies, such as the production of liquid fuels from shale and biomass, are not expected to make major contributions by 2000.

The economic advantages of coal and nuclear power become overwhelming for electric utilities. Industry's energy growth is derived entirely from coal and electricity. Transportation's relatively small growth comes mostly from oil. The residential/commercial sector grows mostly with electricity. The actual breakdown is shown in table 2 for all scenarios.

125-Quad Scenario

The same general price structure is assumed to prevail as in the previous scenario, but the less elastic demand leads to higher consumption. It is assumed that national policies result

Table 2.— Energy Supply and Demand Scenarios

	Type			Coal			Oil			Gas				Solar and other		
	Total	Electric"	Direct	Total	Electric	Direct	Total	Electrlc	Dlrect	Total	Electric	*		Total	Electrlc	Direct
1975 (actual)"".	73.1	20.2	52.7	15.3	8.8	6.5	32.6	3.2	29.4	19.9	3.2	16.7	1.8	3.2	3.2	0.0
Transportation	188	1	187			0			180			0 6				
Resldenttal/commercial	257	120	136			3			5 8			7 6				
Industrial	238	8 0	157			15			5 6			8 5				
Metallurgical	2 2		2 2			2 2										
Exports	18		18			18										
Stock changes	7		7			7										
1 0 0 Q u a d s .	100.0	42.5	57.5	31.1	20.2	10,9	30.1	1.7	28,4	17.2	1.0	16.2	14.5	7,1	5.1	2.0
Transportation	222	0 4	218			0			212			0 6				0
Resldentlal/commercial	336	21 1	125			5			3 8			7 2				10
Industrial	369	210	159			31			3 4			8 4				10
Metallurgical	2 7		2 7			2 7										
Exports	4 3		4 3			4 3										
Stock changes	3		3			3										
125 Quads .'.	125,0	53.8	71.2	37.8	26,4	11.4	40.4	2.2	38.2	19,1	1.5	17.6	18.6	9.1	5.1	4.0
Transportation	281	0 4	277			0			270			0 7				0
Resldentlal/commerc [al	444	294	150			5			4 6			8 0				2 0
Industrial	449	240	209			3 4			6 6			8 9				2 0
Metallurgical	2 8		2 8			2 8										
Exports	4 4		4 4			4 4										
Stock changes	4		4			4										
150 Quads .	150.0	67.8	62.2	41.3	28.9	12.4	48.4	4.0	44.4	26.4	3.0	23.4	26.8	7.1	5.1	2.0
Transportation	315	0 6	309			0			300			0.9				0
Resldent!al/commercial	542	350	192			0 5			6 4			11.4				10
Industrial	564	322	242			4 0			8 0			11.1				10
Metallurgical	3 0		3 0			3 0										
Exports	4 5		4 5			4 5										
Stock changes	4		7			4										

. All **values in** columns **labeled** electricr are for the heat produced at the powerplant. The values for hydroelectric power under solar and others represent the heat that would have heen required at a typical **thermal generating stattion to** produce the same electrical power

" Derived from Bureau of Mines Department of **the** Interior press release of Mar. 14, 1977.

in a significant increase in the availability of imported oil, and a vigorous expansion in electric power generation. These steps are required by the assumed increase in the consumption of petroleum in the transportation sector and by a greater demand for electric power. I n providing for the increased electric power, coal- and nuclear-generated power are assumed to share equally in the expansion, and geothermal energy is starting to become significant. Both the industrial and residential/commercial sectors are turning to the direct use of solar energy.

Under this scenario, coal does not surpass oil as the leading fuel, largely because of increased imports.

150-Quad Scenario

In addition to the increased availability of oil and gas, nuclear power grows at a more optimistic rate. The economic advantages of these fuels limit the growth of coal to little more than that of the 125-Quad case, and actually makes solar energy less attractive than for slower growth scenarios.

Interpretation

An infinite variety of scenarios can be drawn to meet any given demand scenario. The actual mix wit I depend upon relative prices, fuel availability, and the other characteristics listed above. Federal policy will have a considerable influence on the relative level of each fuel as well as on the level of demand. Much has been said here of the importance of the availability of oil and gas, but little about their actual availability. A detailed analysis of the subject is beyond the scope of this study, but the values here are consistent with other recent studies. The higher estimates could be r-net only with a substantial fraction of imported oil. If for political reasons it is necessary to strictly limit imports, other fuels could probably not be expanded much beyond the levels of the 150-Quad scenario to meet the deficit. Nuclear energy has in the past been projected for much higher levels than the highest in table 2 (500 plants of 1,000 MWe). Only about 200,000 MWe have been ordered so far, and many of these projects are inactive. I n order to exceed 500,000 MWe by 2000, all these plants will have to be completed and more than *30* ordered each year throughout the 1980's. This is about the maximum rate of orders ever and might be accommodated by the industry, but utilities are showing no signs of resuming ordering at such a level. A utility ordering a reactor now faces considerable uncertainty over regulatory delays, expensive redesigns and retrofits, public opposition, and perhaps eventually, fuel shortages unless unproven uranium reserves are discovered or the breeder reactor is commercialized. Hence the levels assumed here are unlikely to be exceeded.

PROJECTIONS OF COAL PRODUCTION AND USE

The scenarios of the previous section all show coal to be the fuel of greatest total growth, This growth can occur in a variety of ways and places. The primary distinction in use is between electricity generation and direct heat applications. At present, about 70 percent of the coal mined in the United States is burned for electricity, and the bulk of coal's growth will be in that sector. Direct use by industry is the only other large-scale use considered here. The historical distribution by end-use sector is shown in figure 1. The virtual disappearance of the transportation and retail (essentially the same as residential/commercial) markets is apparent, as is the growing dominance of the utility sector. Also included in figure 1 are the projections to meet the scenarios of the previous sections. Table 3 summarizes the coal consumption of the three scenarios.

Coal-based synthetic fuels are another frequently mentioned possibility. Projections of several million barrels per day equivalent by 2000 have been made, but these are becoming increasingly improbable. In order to build up the industry to meet these levels, a major commitment would have to be made— soon. Coal is an economically rational source of energy when electricity is desired, but for liquid or gaseous fuels, as long as natural sources are available at one-third to one-half the cost of synthetics, there is little incentive for any individual user to turn to the latter. A future OTA report will address the fundamental questions raised by the previous sentence: the logic of electricity vs. synthetics when natural fuels are limited, what these limits are, and the rate at which a synthetic fuels industry can be developed when needed. To the extent that any coal-based synthetic fuel production does occur, this analysis assumes it would come at the expense of electric generation or oil imports. The former is unlikely to occasion any significant change in the impacts discussed in this report. The latter possibility is accounted for by a slight increase in the coal production levels of the previous section.

As discussed in the previous section, coal as a fuel presents a set of characteristics that potential users will compare to alternative fuels; The balance, and hence the eventual level of coal consumption may be shifted by changes in several factors in addition to growth in demand for electricity and industrial processes that can use coal or coal-derived electricity. These factors, which include technological improvements and regulatory restrictions, are discussed in detail in chapter IV. This section analyzes the demand of the users consistent with the scenarios, and the patterns of supply needed to meet the demand.

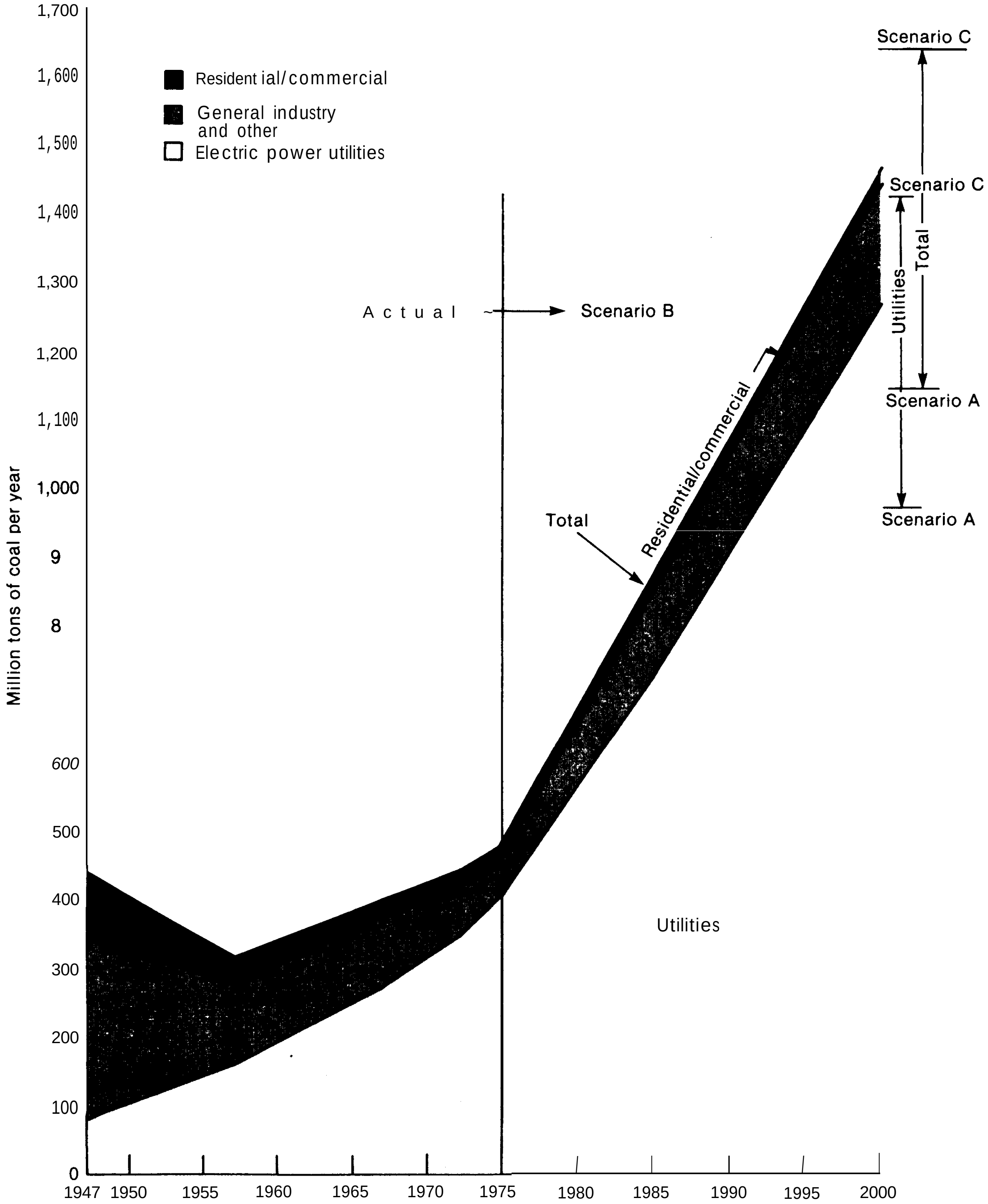
Electric Power Generation

Util ties currently produce about 44 percent of the r electricity with coal. The major alternative for the rest of this century is nuclear power. Most new utility demand for coal will be from new powerplants, as conversion of existing plants to coal will be quite difficult and expensive.

The status of coal-fired electric power capacity in megawatts as of September 1978 is as follows:

Existing	*Planned or under construction*	*Total*
220,583	*152,521*	*373,104*

Figure 1.—Combustion of Coal and Lignite by End” Use Sector



SOURCES *Annual Report to Congress,* Energy Information Adminlstration, Department of Energy, vol. III, 1977, and the Off Ice of Technology Assessment

Table 3.—Coal Consumption Projections
(millions of tons)

Scenario	Total production	Utilltles	Industry	Resldentlal/ commercial	Total domestic combustion	Potential synfuels	Nonenergy	Exports	Addltlons to stocks
1975	655	403	62	12	477	0	83	67	32
1985									
A	955	675	90	15	780	0	95	70	10
B	1050	725	120	15	860	0	95	80	15
c	1145	775	150	15	940	0	100	90	15
2000									
A	1505	965	150	25	1140	65	100	185	15
B	1845	1275	160	25	1460	70	105	190	20
c	2110	1410	200	25	1635	145	110	200	20

Because of lengthening construction schedules, it is unlikely that any plants not included in these figures would be operating by *1985;* the above total of 373,104 MW is thus an upper limit for 1985 capacity estimates.

If recent history is a guide, some of the units planned but not yet under construction will be dropped, and some construction schedules will slip. Some older units will also be retired, though probably only a few thousand megawatts worth over the next decade. Other old units will be downgraded from baseload to intermittent operation. This procedure was more pronounced in the past because new plant efficiencies were rising, making the newer plants cheaper to operate, but this trend has leveled off since the early 1960's. I n fact, plants with scrubbers are less efficient and more expensive to operate. Utilities may favor the use of older plants when they do not need all their capacity, a factor that will tend to make attainment of clean air standards more difficult than expected.

The National Electric Reliability Council is predicting 309,476 MWe capacity (of units greater than 25 MWe) by 1985, consuming 824 million tons of coal. The above concerns indicate this is an optimistic schedule. If all plants with prevention of significant deterioration permits are completed on schedule, and if 3,000 MWe are retired, there will be 301,000 MWe, but a more conservative estimate might be 295,000 MWe. This would correspond to coal consumption of perhaps 775 million tons. This is obviously still a huge jump over the 1977 utility use of 475 million tons (estimated). If major deferrals result from a continuation of the very low growth of the past few years, utility demand may be as much as 100 million tons lower.

Beyond 1985, projections are highly uncertain. A growth rate of 5 percent from 295,000 MWe in 1985 for the remainder of the century would result in about 450,000 MWe of coal-fired powerplants by 2000. A growth rate nearer historical levels would lead to 600,000 MWe. These would lead to coal demands of 1,400 million and 2,000 million tons annually. (Increases in coal are not proportional to increases in capacity, because the shift to lower heat value Western coal requires more tons for the same electrical output.) Utility forecasts are changing rapidly, mostly towards lower estimates. Historical growth patterns appear to be unlikely to continue, as pointed out in the previous sections. The year 2000 coal-fired electric generation of tables 2 and 3 is equivalent to about 330,000 to 450,000 MWe. The exact level will depend primarily on the level of demand for electricity and the competitiveness of nuclear power; it is therefore quite sensitive to policy decisions affecting nuclear power and the economics of coal.

Decentralized Electric Power Generation: An Alternative Approach?

The projections have implicitly assumed that the utility industry would continue the trend toward larger (600 to 1,200 MWe) generating plants. Existing generating plants in 44 States average less than 100 MWe each, but only three States have any planned facilities at that low level, and planned additions in 20 States average greater than 500 MWe. Every State that has planned capacity additions (only Vermont and the District of Columbia have none) will significantly increase the average capacity per plant This trend for generating units may be leveling off, but stations, which can include several units, are clearly still getting larger as sites become scarcer Economics of power plant construction and operation have been the primary cause of the growth in size. The physical size of the plant, and the materials and labor to construct it, increase less than proportionally with its size. Operating costs (excluding fuel) are only slightly higher for a 500 MWe plant than for a 50 MWe plant.

Considerable interest has recently been expressed in some quarters in small, dispersed plants. ("Small" is relative: a 50 MWe plant would serve an average community of 20,000 people.) This interest has been prompted partly by the downtime maintenance experience with large coal-fired powerplants and partly by the environmental and social impacts of large plants and the resulting issues of public acceptability. Appendix I I of volume I I discusses the issue in detail, Smaller plants can in theory be placed closer to the communities they serve because their siting criteria are so much more modest. This dispersal would substantially reduce the need for long-distance, high-voltage transmission, though the distribution system would remain the same. Such a siting policy also raises the possibility of using the waste heat from the plants (about 60 percent of the total heat of combustion) for district heating or industrial processes. The latter in particular, usually called cogeneration, has been espoused as a major element in energy conservation policy. There are no technical barriers to either district heating or industrial cogeneration. Both have been in operation for many years. The major impediments are economics and a variety of institutional problems.

In order to assure continuity of supply, a spinning reserve (virtually instantly available) equivalent to the biggest single unit online must be maintained. The smaller all the units are, the easier it is to assure the same degree of reliability. It should be noted, however, that most utilities are part of large grids. The entire grid shares the spinning reserve, so the excess capacity for each utility is not large.

The present high interest rates throw the economies of scale into question, Interest on capital costs is one of the larger items in the final bill for a large plant that may take 6 or more years to construct. Small plants may take one-third to one-half the time to construct, thus providing a much faster return on their share of the capital. This time factor is also a great advantage to utilities as they plan in this era of uncertainty in load forecasting. Another economic advantage is that the smaller size makes possible the factory fabrication and shipment of components that now must be field fabricated, Factory labor is often cheaper and more productive than construction labor, Community impacts during construction will clearly be less severe for smaller plants. Remote siting of large plants needin$_g$ more than 1,000 construction workers can provoke serious strains in the nearby small communities that must support them temporarily. Construction of small plants near bigger cities would be relatively inconspicuous to the community in-f restructure.

One of the major arguments advanced in favor of decentralized power systems is enhancement of local control, particularly if the plants are owned by a local government or a cooperative. This argument is very difficult to analyze. Until recently, few consumers were concerned with the other end of their powerline as long as the power was there when they flipped the switch, and their bills weren't too high. Obviously many persons feel the latter criterion is not now being met, but it is questionable whether decentralization or local control would provide much relief. The advantages would be more subjective: a sense of involvement and control over factors affecting one's life. It is as easy to name examples showing indifference to involvement (e. g., the difficulty of getting neighborhood committees to do much) as it is to list advantages. Further exploration of this issue is beyond the scope of this report.

There would probably not be a great deal of difference in total environmental impacts between a centralized and decentralized system of the same capacity. Total emissions could be about the same, and though they would be more dispersed for the small-scale system they would probably also directly affect more people. Lower stack heights could lead to a different mix of local and long-range transport pollutants, as discussed in chapter V. Insofar as any system includes district heating or cogeneration, thermal pollution and the combustion of other fuels would be substantially reduced.

Small plants and dispersed siting have their disadvantages, of course. Construction clearly requires more materials and possibly more labor for the same output, Environmental control measures are often easier and cheaper to implement in large plants. Flue-gas desulfurization, for example, may prove prohibitively expensive for small units. Hence even if decentralization proves advantageous otherwise, full realization may have to await commercialization of developments such as fluidized-bed combustion or highly cleaned coal, which are discussed in the next chapter. It is also likely that public heath impacts of dispersed facilities would be greater even for the same efficiency of control, simply because such plants would be in more densely populated regions.

Fuel delivery and waste removal can be major drawbacks to dispersed units. Unit trains have cut transportation costs for big plants to about half that of conventional trains, but these and slurry lines would not be practical for small plants. Insofar as the plants are located in more densely populated areas, transport would be more obtrusive, especially if trucks are used.

Some of the problems and expenses facing a utility trying to get a plant constructed and online are not markedly different for a small plant. Hence the total effort for several small plants will be greater than for one large plant. Operating costs have already been mentioned. Licensing would be another. Opposition to particular sites may not be much less intense, and if a close-in site is selected, opposition could be much more intense than for a remote site. This factor is further discussed in chapter IV.

This largely qualitative discussion is ambiguous. The economic and environmental tradeoffs are uncertain, and the social impacts depend on values and expectations. Thus neither approach appears to have an overwhelming advantage — a striking observation, as the trend has been so strong to centralization. The economies of scale discussed above are not the whole cause of the trend. Regulatory constraints are another factor as suggested by the controversial Avech-Johnson[5] effect:

> Utilities subject to a constraint on their rate of return have incentives to expand the size of their rate base to unjustifiable levels.

Thus while large central stations are clearly in the utilities' best interest they are not necessarily in society 's. Reversal of the trend may require drastic changes in utility operations and ownership, and in regulatory practices. Nevertheless, the subject seems worthy of more detailed analysis. Particular attention should be directed to the States with utility systems most resembling the decentralized concept. Michigan, Nebraska, Wisconsin, and lowa, for example, have many small generating utilities and facilities and access to coal.

Industrial Use of Coal

The outlook for coal use by industry is quite different from that for utilities. Industry burned 60 million tons in 1976, representing only about 10 percent of all energy purchased by industry. Both figures have been dropping steadily for 30 years, and there appears to be no major effort on industry's part to reverse the trend. These factors have left industry as the sector of greatest opportunity for policy actions for conversion from oil and gas to coal. A recent report by the Congressional Budget Office' extensively analyzed the use of fuel by manufacturers and the prospects for increasing their use of coal. This report found that coal use could be raised by about 90 million

'H. Avech and L. Johnson, "Behavior of the Firm Under Regulatory Constraint," *American Economic Review, 211* (December 1962), pp. 1059-69.

"'Replacing Oil and Natural Gas With Coal: Prospects in the Manufacturing Industries, " Congress of the United States, Congressional Budget Office, August 1978, tons above present levels by 1985 under various tax policies.

Industry uses most of its energy for process steam, electric power generation, and direct heat applications. Most of these functions could in principle be provided by coal, but conversion of existing oil- and gas-fired facilities to coal will be quite difficult. There is little experience with large coal-fired furnaces for direct heat rather than steam generation, so most applications will be for steam-raising boilers. Boilers or furnaces not designed to burn coal must be essentially replaced to accommodate coal, and entirely new storage and handling equipment must be added. Coal requires twice the storage volume for the same heat content as oil, and the handling equipment is larger and more expensive. Ash removal equipment and disposal must also be included. Pollution control equipment is generally necessary, even when not required for oil or gas. If industry is to be held to emission limitations similar to those being promulgated for utilities, only the very largest facilities will be able to consider coal. New technologies such as fluidized-bed combustion or synthetic fuels would be necessary to meet both coal use and environmental goals. Strong financial incentives above the fuel cost savings must be considered if it is desired to force these conversions. New facilities are more favorable targets. Energy consumption by industry, however, is expected to grow much more slowly than consumption by utilities. Hence industry cannot adopt coal as a major fuel without wide-seale replacement of existing units.

Guiding industry toward coal will be difficult but not impossible. Small powerplants and process steam generators are used throughout industry. Coal boilers are now available to cover a wide range of needs. These units can be installed much faster than utility powerplants. Some of the small units (up to about 1 ton of coal burned per hour or equivalent to about 2 MWe) can be manufactured and delivered as a package. Thus if the economics and the less tangible factors, such as reliability of supply, prove favorable, industrial coal use could rise rapidly. Industrial process heaters must be designed with a specific purpose in mind. The cement industry uses several million tons of coal annually for direct heat and could expand this relative to other fuels. The glass and metals industries may also find coal use advantageous.[7] The 1962 Census of Manufactures by the Bureau of Census[8] reported that the chemical, paper, and food industries were also major users of coal, with most industrial use in the East North Central, Middle Atlantc, and South Atlantic regions.

Coal use by industry will almost certainly reverse its long-term decline because of the fuel cost advantage and policy initiatives. Hence a low estimate for 1985 for industrial use of steam coal is 90 million tons. On the higher side, perhaps 150 million tons might be feasible. By 2000, industrial coal will have risen even without further policies to encourage it. A minimum figure for energy use might be 150 million tons. An upper limit is almost arbitrary as the outcome is sensitive to so many factors, but for the purposes of this report 200 million tons is used. Oil and gas will be the preferred alternatives as long as they are available at competitive prices. Solar energy could prove uniquely advantageous for industry if the costs (including reliable backup) prove competitive, as it could be used to avoid both fuel and emission restrictions.

Residential and Commercial Use of Coal

Coal has nearly disappeared as a fuel for homes and commercial facilities over the last three decades. In 1948 coal provided 50 percent of the energy used in this sector, but this has declined to less than 2 percent. ' The reasons are obvious: for the small user in particular, coal required dirty and noisy truck deliveries, messy storage in the house, and daily

‘Frank H. Boon, “Industrial Consumers May Loom Very Large In Coal’s Future, ” *Coa/ Age,* February 1976

[8]Richard L Gordon, reprinted in *Coal In the U.S. Energy Market,* Lexington Books, 1978

‘E N Cart, Jr , M, M Farmer, C E Johnlg, M Lleberman, and F M, Spooner, “Evaluation of the Feasiblllty for Widespread Introduction of Coal Into the Residential and Commercial Sector, ” Government Research Laboratories of EXXON Research and Engineering Company for the Council on Envlronmental Quallty, April 1977 stoking and ash removal, and it left the air laden with smoke and fumes. Most Americans turned to oil and gas, and the coal retail market (essentially the same as residential and commercial use) nearly followed the transportation market into oblivion as shown in figure 1. Recently, however, concerns over the price and availability of oil and gas have sparked a flurry of inquiries, though not yet substantial orders, to manufacturers of coal-fired equipment. Although a return to coal might at first appear unlikely, the scenario warrants examination because of the large energy consumption of the residential and commercial sectors (21 percent of the U.S. energy budget). Appendix III analyzes this potential in greater detail.

The retail market now is about 12 million tons per year, including anthracite. Most of this is consumed in the Appalachian coal-producing States, plus New York, Illinois, and Michigan. There is no national or even regional market structure for coal or furnaces. Dealers purchase coal from the mines (usually small ones) and have it delivered by train or truck. As the purchases are usually made on a one-time basis (spot market) in small quantities, and delivery is made without the economies of scale utilities enjoy, the retail price of coal is startlingly high, perhaps $80 to $100 per ton. These **prices are probably enough** in themselves to preclude a resurgence of coal use, but they could drop if the retail market develops into a more stable operation, Many mines sell coal by the pickup truck load at about $30 per ton, and retail markets in the mining areas carry it at $40 to $45 per ton, but this will benefit only those living near coalfields.

Although improvements in equipment, such as automatic stokers, and improvements in combustion technology could increase residential use of coal, the scenarios used here do not anticipate much growth. Coal-fired district heating plants (such as the U.S. Capitol Power Plant) may be the only way that coal could experience a resurgence in the residential market, as such large plants make stringent environmental controls practical and relieve the end-use consumer of the inconvenience. Large commercial customers may, however, find it economical to use coal in either conventional boilers or fluidized-bed combustion units.

Given the marginal economic advantages, the choice of coal as a heating fuel for the residential/commercial sector is not likely to be based on economic or financial calculation alone. Convenience and reliability of supply will probably be of major concern. The projected scenarios envision residential/commercial use of coal to double from 12 million tons in 1975 to 25 million in the year 2000, a growth that is virtually immaterial to the national energy picture, but perhaps environmentally significant in some regions.

Distribution of Coal Combustion and Production

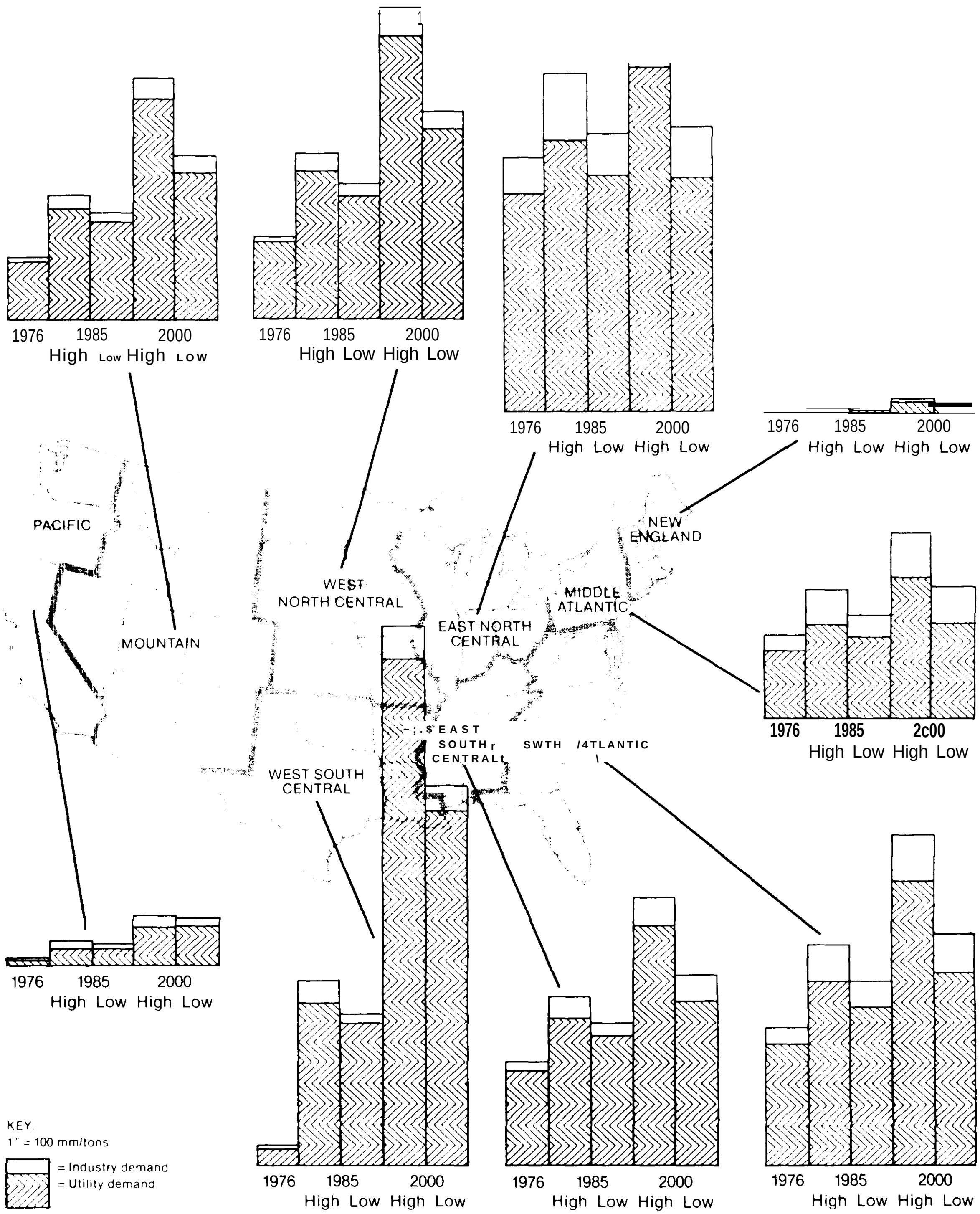
The national levels of consumption shown in table 3 will not be uniform across the country. , Most coal will be burned within a few hundred miles of the coal fields, as it is now. The regional distribution of use is shown in figure 2 and listed in table 4. Production by State is shown in table 5. Even more than for the national levels, these projections are not estimates but indications. The actual distribution will depend on relative changes in regional cost of production and transportation, success in controlling emissions of high-sulfur coal, customers' perceptions of the reliability of delivered supply, and other unpredictable factors. Policy decisions affecting these factors can produce inter regional shifts of several hundred million tons annually by 2000. For instance, the trend towards Western coal is expected here to moderate after 1985 because of the full scrubbing regardless of sulfur content required by the Clean Air Act Amendments of 1977 (discussed in chapter IV, pages 167-1 75).

The manpower required to produce this coal (assuming no change in mine productivity) is shown in table 6.

Conclusions

The coal projections discussed here appear to be achievable under the present legal/regulatory and economic climate. If actual use

Figure 2.—Coal Combustion Distribution



NOTE: Bureau of Census geographic regions as reported in EEI Statistical Yearbook

SOURCE: Office of Technology Assessment

Table 4.—Powerplant and Industry Coal Combustion
(million/tons)

Region"	6		1985				000			
	Utility	Industry	High utility	High industry	Low utility	Low industry	High Utllity	High industrv	Low utility	Low industry
New England	0.8	o	3		2	o	7	2	5	1
Middle Atlantlc.	45	10.85	64	2:	58	15	96	30	65	25
South Atlantic	83.3	10.85	124	25	106	16	193	24	130	27
East South Central	84.7	6.33	101	15	88	10	165	20	112	17
West South Central	12.7	1.61	112	15	98	6	344	21	234	18
Pacific .,	4	.4	11	5	10	3	27	7	27	5
Mountain ~	39	3		10	66	6	151	14	102	10
West North Central.	52	3	~	12	66	6	193	16	131	12
East North Central	145	24.4	185	45	161	28	234	57	159	35
Total.	4465	80.64	775	150	675	90	1410	200	965	150

'New England Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island
Middle Atlantic New York, Pennsylvania, New Jersey
South Atlantlc Maryland. Delaware. West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida
East South Central -Kentucky, Tennessee, Mississippi Alabama
West South Central Arkansas, Louisiana, Oklahoma, Texas
Mountain. New Mexico, Arizona, Utah, Colorado, Nevada, Idaho, Montana. Wyoming
Pactfic- California, Oregon, Washington
West North Central. North Dakota, South Dakota, Minnesota, Iowa, Nebraska, Kansas, Missouri
East North Central- Wisconsin, Illinois, Indiana, Michigan, Ohio

Table 5.—Coal Production Projections
(million of **tons** per year)

	Surtace						Uncle ıround						Total"				
			P ıduct ɔn range						ɔducti n rar						Produc ɔn rar ɘ			
	1977 production[a]	Planned capacity[b]	19 ɔ		200(-		1977 production[a]	Planned capacity[b]	1ƞ ɔ		2)		1977 production[a]	1985		2000	
			Low	ıigh	Low	High			Low	High	Low	High		Low	High	Low	High
Appalachia																	
Alabama	15	3	12	15	10	15	7	14	15	18	27	40	22	27	33	37	55
Georgia	—	1	—	1	—	1	—	—	—	—	—	—	—	0	1	0	1
Kentucky east	51	6	36	40	40	49	41	34	50	58	85	115	92	86	98	125	164
Maryland	3	2	3	4	2	3	—	2	1	2	2	3	3	4	6	4	6
Ohio	32	3	20	25	30	40	14	12	18	20	32	50	46	38	45	62	90
Pennsylvania	45	3	30	33	15	20	38	20	40	47	80	100	83	70	80	95	120
Tennessee	6	—	4	5	3		5	1	3	4	4	5	11	7		7	9
Virginia	12	—	7	9	5	:	26	6	21	24	25	40	38		3:	30	48
West Virginia	21	5	18	23	25	35	74	43	77	87	125	187	95	: :	110	150	222
Total Appalachia	185	23	130	155	130	175	205	132	225	260	380	505	390	355	415	510	680
Midwest																	
Missouri	7	—	3	4	5	10	—	—	—	—	—	—	7	3	4	5	10
Illinois	24	10	23	30	39	55	30	30	39	53	75	110	54	62	83	114	165
Indiana	27	11	25	32	21	32	1	—	—	—	10	25	28	25	32	31	57
Kentucky west	28	4	21	24	28	35	23	9	20	25	33	42	51	41	49	61	77
Oklahoma	5	1	3	5	2	3	—	2	1	2	2	3	5	4	7	4	6
Total Midwest	91	26	75	95	95	135	54	41	60	80	120	180	145	135	175	215	315
West																	
Arizona	11	3	11	13	6	11	—	—	—	—	—	—	11	11	13	8	11
Colorado	6	31	21	30	45	64	4	30	18	20	25	30	12	39	45	70	94
Montana	29	63	55	65	130	200	—	—	—	—	5	10	29	55	60	135	210
New Mexico	11	59	38	50		120	—	1	—	1		5	11	3$	43	77	125
North Dakota	12	53	37	47	: ;	135	—	4	2	3	:	4	12	39	45	83	139
Texas	17	58	43	54	85	140	—	—	—	—	—	—	17	43	48	85	140
Utah	·	16	10	10	6	10	9	39	29	33	39	49	9	38	43	47	59
Washington	5	1	5	6	9	15	—	—	—	—	1	2	5	5	6	10	17
Wyoming	45	268	198	220	260	310	—	3	1	3	5	10	45	192	207	265	340
Total West	141	553	415	495	700	0Q5	13	77	50	60	80	110	154	460	510	780	1,115
National total	417	602	620	745	925	315	272	250	335	400	580	795	689	955	1,145	1,505	2,110

[a]1978 *Keystone Coal Industry Manual* p 666 (estimated)
bibid. pp. 674-685 data adjusted to eliminate present production capacity

does not rise to these levels, it is more likely to be from lack of demand rather than restricted supply, but several factors could induce the latter situation, as discussed in chapter IV. Demand for coal could remain below these levels either because energy demand has been successfully curtailed or other fuels prove unexpectedly bountiful. Neither situation calls for remedial action, though attention could still be directed to reducing the negative impacts of coal (see chapters V and Vi).

If it is deemed necessary to achieve projections higher than these because of disappointing oil and gas discoveries or inadequate growth by nuclear and other energy sources, attention may have to be directed to loosening environmental and other restrictions or accelerating development of technologies that better accommodate them. Coal's growth rate may also need acceleration beyond that dictated by the immediate market conditions, possibly because of an unexpected sharp drop in oil or gas availability. Then greater efforts of coercion or incentives would be required, possibly coupled with a streamlining of the process of getting mines into production.

These scenarios are used as guidelines in the following chapter. Detailed analyses of the implacations, such as emission quantification, have not been made, as the results would not vary greatly from published analyses.

Table 6.—Coal Mine Employment Forecasts

	Surface				Underground				Total			
	1985		2000		1985		2000		1985		2000	
State	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Appalachia												
Alabama	3,290	4,080	2,720	4,080	9,430	11,320	16,970	25,150	12,700	15,400	19,690	29.230
Georgia	—	240	—	—	—	—	—		—	240	—	—
Kentucky	6,725	7,470	7,470	9160	20,010	23,210	34,010	46010	26,740	30,680	41480	55,170
Maryland	575	770	380	575	475	950	950	1,420	1,050	1,720	1,330	1,995
Ohio	3,210	4,010	4,810	6,420	9,990	11,100	17,7611	27,750	13,200	15110	22,570	34,170
Pennsylvania	6,070	6,6&3	3,040	4,050	22,090	25,960	44,180	55,230	28,160	32.640	47,220	59,280
Tennessee	940	1,180	710	940	1,380	1,840	1,640	2,300	2,320	3,020	2,550	3,240
Virginia	1,480	1,910	1 060	t 700	11,090	12,670	13,200	21,110	12,575	14,580	14,260	22,810
West Virginia	4,410	5,630	6,120	8,570	42,480	47,990	88,950	103,160	46,890	53,620	75,070	111,730
Total Appalachia	26,680	31,970	26,310	35.495	116,945	135,040	197,8&"	282,130	143,630	167,010	224,170	317,625
Midwest												
Missouri	590	790	990	1.970	—	—		—	590	790	990	1,970
Illinois	3,980	5,170	6,720	9,470	12,440	16,910	23,920	35,090	18,400	22,080	30,640	44,560
Indiana	3,510	4,490	2,950	4,490	—	—	2,820	7,080	3,510	4,490	5,770	11,550
Kentucky (west)	2,960	3,380	3,950	4,930	6,280	7,850	10,360	13,180	9.240	11,230	14,310	18,110
Oklahoma	845	1,410	560	850	1,010	2,020	2,020	3,030	1,855	3,430	2,580	3,880
Total Midwest	11870	15,240	15,170	21,710	19,730	26,780	39,120	58,360	31595	42020	54,290	80,070
West												
Arizona	660	780	480	660	—	—	—	—	660	780	480	660
Colorado	1,920	2,740	4,110	5.850	7,840	8,720	10,900	13,070	9,760	11,460	15,010	18,920
Montana	1,800	2,130	4,260	6,550	—	—	2,270	4,540	1,800	2,130	6,530	11,090
New Mexico	3,090	4,070	6,100	9,760		490	970	2,430	3,090	4560	7,070	12,190
North Dakota	1775	2,250	3,840	6480	910	1,360	1,360	1,820	2,685	3,610	5,200	8,300
Texas	2,340	2,940	4,630	7,630	—	—	—	—	2,340	2,940	4,630	7,630
Utah	1,670	1,670	1,330	1,670	9,520	10,830	12,800	16080	11,190	12,500	14,130	17,750
Washington	7641	910	1,360	2270	—	—	860	1,720	760	910	2.220	3,990
Wyoming	1210	1,350	1,660	1,910	420	1,260	2,110	4,210	1,625	2610	3710	6,120
Total West	15,200	18,840	27710	42,780	18,690	22,660	31,270	43870	33,900	41500	58,980	86,650

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