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SYMPOSIUM ON ENERGY AND THE ENVIRONMENT: IS COAL THE KEY TO THE SOLUTION?

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*Bernard D. Blaustein**
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PREFACE

This symposium is designed to examine what impact certain federal legislation has had and will have on coal production and utilization. The articles will explore the intricacies of the Federal Coal Mine Health and Safety Act of 1969, the Clean Air Act as amended in 1970, the Energy Supply and Environmental Coordination Act of 1974 and the Energy Policy and Conservation Act of 1975. It is the purpose of this article to indicate that significant non-legal, and in particular technological, factors exist with efforts to increase coal production and utilization. These technological problems raise important issues, some of which fall within the purview of the above statutes, and some of which do not. Further, it is hoped that, because of the technical approach of this article, a greater understanding of the magnitude of the problem of energy production and utilization will result.

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I. Introduction

Our American society is highly industrialized, highly mechanized and based on an energy-intensive economy. Because we have had indigenous, and until recently, abundant, low-cost sources of energy, the per capita energy consumption in the United States is the highest of the industrialized countries of the world.[1] Almost all of this energy has been and will continue to be supplied in the near future by fossil fuels (petroleum, natural gas and coal), as shown in Table I.[2]

If we are to increase our energy supply to meet higher projected levels of demand in the years to come[3] and to concurrently reduce our reliance on imported supplies of energy, a major increase in United States coal production must be one necessary part of our overall energy policy.

It will be helpful initially to provide some background as to the origin and chemical composition of coal. The most widely accepted theory on the origin of coal is that it is the result of the incomplete decay of plant material.[4] This theory embraces two broad processes: the period of accumulation and preservation of plant remains as peat deposits, and the period of conversion of these organic remains or peat deposits to coal.

Coal, although a rock, is not a true mineral, but is a fossilized plant material that consists of complex chemical structures containing primarily the elements carbon, hydrogen, oxygen, nitrogen and sulfur.[5] Most of the structure of coal consists of carbon-containing components, that is, organic compounds. Most of the other naturally occurring elements can be found in coal, but generally in smaller quantities, present as mineral matter.[6]

Upon combustion in the presence of air, the chemical bonds between the constituent elements of the organic fraction of coal are

1. U.N. Dep't of Economical and Social Affairs, World Energy Supplies, 1970-1973, at 12-35 (1975) (Statistical Papers Series J, No. 18). Total per capita consumption of energy for the United States for 1973 was equivalent to 11,897 kilograms (13.1 tons) of coal. Kuwait, Qatar, United Arab Emirates and the Christmas Islands (Territory of Australia) had higher values for per capital energy consumption.

2. U.S. Dep't of the Interior, Energy Perspectives, A Presentation of Major Energy and Energy-Related Data 34 (1975) [hereinafter cited as Energy Perspectives].

3. *See* text at 556 *infra*.

4. *See* Chemistry of Coal Utilization-Supplementary Volume, at 1 (H. Lowry ed. 1963).

5. *Id.* at 202-31.

6. *Id.*

TABLE I

U.S. ENERGY CONSUMPTION TRENDS
(Quadrillion Btu)*

YEAR	COAL	PETRO-LEUM	NATURAL GAS	HYDRO-POWER	NUCLEAR	FUEL WOOD	TOTAL
1850	.2	—	—	—	—	2.1	2.3
1860	.5	—	—	—	—	2.6	3.1
1870	1.0	—	—	—	—	2.9	4.0
1880	2.0	.1	—	—	—	2.9	5.0
1890	4.1	.2	.3	—	—	2.5	7.1
1900	6.8	.2	.3	.3	—	2.0	9.6
1910	12.7	1.0	.5	.5	—	1.9	16.6
1920	15.5	2.6	.8	.8	—	1.6	21.3
1930	13.6	5.4	2.0	.8	—	1.5	23.3
1940	12.5	7.5	2.7	.9	—	1.4	25.0
1950	12.9	13.5	6.2	1.4	—	1.2	35.2
1960	10.1	20.1	12.7	1.7	—	—	44.6
1970	12.7	29.5	22.0	2.7	.2	—	67.1
1971	12.0	30.6	22.8	2.9	.4	—	68.7
1972	12.4	33.0	23.0	2.9	.6	—	71.9
1973	13.4	34.7	22.8	2.9	.9	—	74.7
1974	13.0	33.8	22.3	2.9	1.2	—	73.2

*"Btu" is an abbreviation for British thermal unit. It is defined as the quantity of heat, which is a form of energy, necessary to raise the temperature of a pound of water from 39°F to 40°F. A conceptualization of the magnitude of the Btu may be provided by the following examples:

1. Approximately 2,000 Btu's are required to operate a lightbulb rated at 100 watts for one hour.
2. A furnace in an average 6-7 room single family residence typically will be rated at 100,000 Btu; *i.e.*, during one hour of continuous operation, 100,000 Btu's of heat will be liberated from the fuel utilized.

A quadrillion is 1,000,000,000,000,000 or a million-billion. Transposing 1 quadrillion Btu's into the units of measure more commonly associated with the particular fuels used,

1 Quadrillion Btu
≑ 170 million barrels of petroleum
≑ 41 million tons of Eastern bituminous coal
≑ 57 million tons of Western sub-bituminous coal or lignite
≑ 1 trillion cubic feet of natural gas
≑ 100 billion kilowatt-hours of electricity
[based on a 10,000-Btu/kw-hr heat rate]

Hereinafter, a quadrillion Btu will be referred to as a Quad.

broken and smaller molecules (primarily carbon dioxide and water) are formed. This combustion process is exothermic, that is, energy releasing. The released energy can be utilized in any manner technologically feasible, *e.g.*, to heat a boiler to produce steam to drive a turbine to generate electricity. This exothermic process of combustion is essentially the same for any fossil fuel. Natural gas and petroleum are more readily used than coal however, because neither of these fuels contains as much sulfur, nitrogen or mineral matter as coal. The higher levels of sulfur and nitrogen present in coal result in the formation of more of the air pollutants, sulfur oxides[7] and nitrogen oxides, when coal is burned.[8] Serious environmental problems are created when these pollutants are emitted into the environment.[9] The problems associated with the disposal of ash (which forms from the mineral matter present in the coal) are both environmental and economic in nature.

Figure I shows the geographical distribution of the coal fields in the United States.[10]

According to Paul Averitt of the U.S. Geological Survey,[11] the coal resources of the United States (including Alaska) are estimated to be 4.0 trillion tons.[12] Of this total, 1.7 trillion tons are "Identified resources"; of this, 0.434 trillion tons constitute the "Reserve base." The remaining 2.3 trillion tons of coal are considered to be "Hypothetical resources."[13] Averitt compares the total resources of coal

7. As a result of combustion, most of the sulfur in coal is converted to sulfur dioxide, SO_2. However, a small amount (less than 3 percent) is converted to sulfur trioxide, SO_3. *See* Address by J. Driscoll, "Stack Sampling Procedures for Determining Sulfur Oxides in Fossil Fuel-Fired Steam Plants," IEEE-ASME Joint Power Generation Conference, Pittsburgh, Pennsylvania, Sept. 27-30, 1970. In order to simplify the terms used, hereafter sulfur oxide emissions will be referred to as SO_2.

8. The presence of nitrogen oxides in the gases resulting from the combustion of any fuel, including coal, can come from either the nitrogen in the fuel or the reaction of molecular nitrogen with the oxygen in the air at the high temperatures of the combustion processes.

9. *See, e.g.*, L. BARRETT & T. WADDELL, COST OF AIR POLLUTION DAMAGE: A STATUS REPORT (1973) (EPA PUB. No. AP-85). This report is a survey of estimations of costs associated with pollution damage.

10. U.S. DEP'T OF COMMERCE, REPORT OF SULFUR OXIDE CONTROL TECHNOLOGY 24 (1975) [hereinafter cited as COMMERCE REPORT].

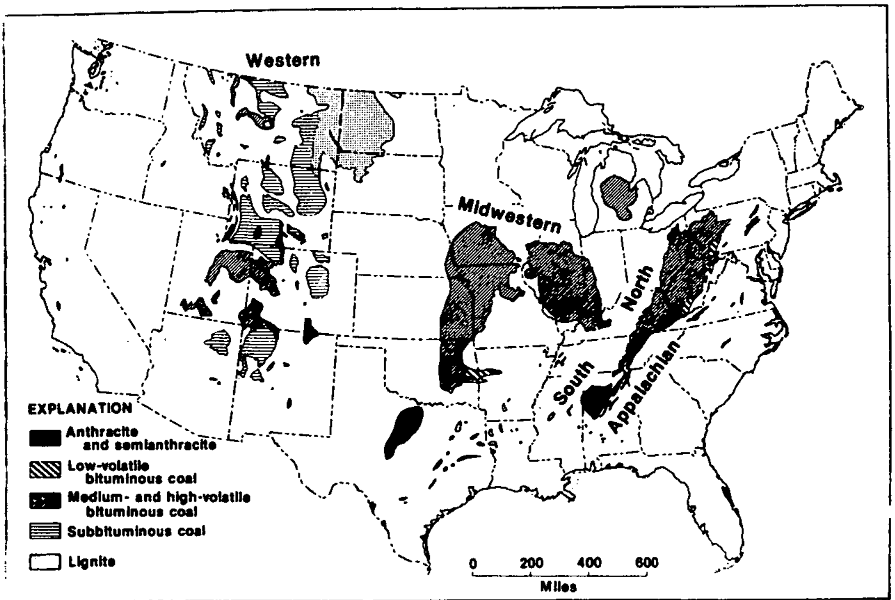
11. P. AVERITT, COAL RESOURCES OF THE UNITED STATES JANUARY 1, 1974 (1975) (U.S. GEOLOGICAL SURVEY BULL. 1412) [hereinafter cited as AVERITT].

12. *Id.* at 1. These 4.0 trillion tons indigenous to the United States constitute approximately 1/5 of the world's total coal resources.

13. *Id.* at 105. Mr. Averitt gives the following definitions:

> **Resources**—Total quantity of coal in the ground within specified limits of bed thickness and overburden thickness. Comprises identified and hypothetical resources.
>
> . . . .
>
> **Identified resources**—Combined tonnage in the measured, indicated and inferred resource categories as defined below. All coal in the identified category is further classified according to rank, thickness of beds, and thickness of overburden.
>
> **Measured resources**—Tonnage of coal in the ground based on assured coal-bed correlations and on closely spaced observations about one-half mile apart. Computed tonnage judged to be accurate within 20 percent of the true tonnage.
>
> **Indicated resources**—Tonnage of coal in the ground based partly on specific observations and partly on reasonable geological projection. The points of observation and

FIGURE I
COAL FIELDS OF THE UNITED STATES



At present, U.S. coal production consists primarily of bituminous coal mined east of the Mississippi River. In the next decade, an increasing proportion of U.S. production will consist of lower-rank (and lower-heating value) subbituminous coal and lignite mined west of the Mississippi River.

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measurement are about 1 mile apart but may be 1-½ miles apart for beds of known continuity.

. . . .

Inferred resources—Tonnage of coal in the ground based on an assumed continuity of coal beds downdip from and adjoining areas containing measured and indicated resources. In general, inferred coal lies 2 miles or more from outcrops or from points of precise information.

Reserve base—A selected portion of coal in the ground in the measured and indicated (demonstrated) category. Restricted primarily to coal in thick and intermediate beds less than 1,000 feet below the surface and deemed to be economically and legally available for mining at the time of the determination.

. . . .

Hypothetical resources—Estimated tonnage of coal in the ground in unmapped and unexplored parts of known coal basins to an overburden depth of 6,000 feet; determined by extrapolation from nearest areas of identified resources.

Id. at 105-06.

and other fossil fuels in the United States to show that on an energy basis, coal constitutes 69 percent of the total estimated recoverable resources of fossil fuels, whereas petroleum and natural gas together constitute only 7 percent. The remaining 23 percent of indigenous fossil fuel resources is found in oil from oil shale, a source not currently used as a fuel.[14]

In 1974, United States coal production was approximately 0.60 billion tons; domestic consumption was 0.55 billion tons and the balance was exported.[15] Total energy consumption, as shown in Table I, was 73 quadrillion Btu, which if produced entirely from coal would have been equivalent to a coal production of approximately 3.1 billion tons.[16] Since coal, our largest fossil fuel resource, *could* supply our *total* energy needs for many decades,[17] it would seem obvious that coal is an under-utilized resource and that we ought to use it to supply an increasing fraction of our energy requirements.

Table I shows the United States energy consumption trends for the period 1850 to the present. The breakdown by use sector for 1974 was: transportation—25 percent; generation of electricity—27 percent; industrial—29 percent; and household and commercial—19 percent.[18] As the data in Table I show, wood gave way to coal as our major energy source, and this in turn was supplanted by petroleum and natural gas.[19] The latter two fuels supplied about 77 percent of our total energy in 1974; coal supplied only about 18 percent. Projections show (Figure II[20] and Figure III[21]) that domestic production of

14. Large deposits of oil shale are indigenous to Colorado, Wyoming and Utah. Technology to recover oil from shale is still in the process of being developed for commercialization.

15. U.S. BUREAU OF MINES, DEP'T OF THE INTERIOR, COMMODITY DATA SUMMARIES 1976, at 40 (1976) [hereinafter cited as COMMODITY DATA-1976].

16. As shown in TABLE I, *supra*, coal furnished 13.0 Quads out of a total energy consumption of 73.2 Quads in 1974. Since United States coal consumption in 1974 was approximately 0.55 billion tons, then (73.2/13.0) x (0.55) or 3.1 billion tons of coal would have been sufficient to supply the total energy consumed in 1974.

17. AVERITT, *supra* note 11, at 13. Total cumulative United States coal production to January 1, 1974, was 39.7 billion tons. The remaining "Identified Resources" were 1771 billion tons. Thus, we have used only (39.7) x (100/1810.7) or 2.2% of the original identified resource to date.

18. W. DUPREE, JR. & J. CORSENTINO, UNITED STATES ENERGY THROUGH THE YEAR 2000, at 8 (rev. ed. 1975) [hereinafter cited as DUPREE & CORSENTINO].

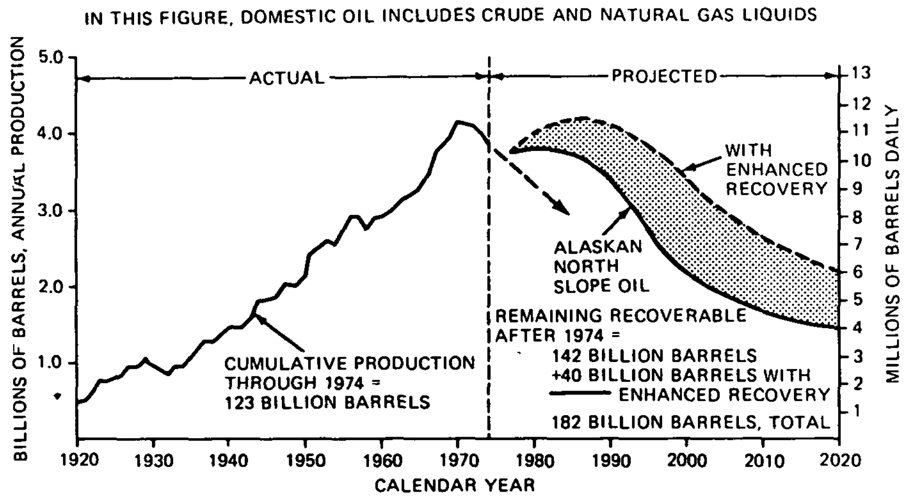
19. As the data in the table indicate, the primary source of our energy has changed every 60-70 years. It should be apparent from this discussion that the next change should occur much more rapidly.

20. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION, 1 A NATIONAL PLAN FOR ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION: CREATING ENERGY CHOICES FOR THE FUTURE, at S-2 (1975) (ERDA-48) [hereinafter cited as ERDA-48].

21. *Id.*

petroleum and natural gas may increase somewhat in the next ten years, but our production of both of these fossil fuels is expected to eventually decrease, beginning no later than sometime in the 1980's.

FIGURE 2
DOMESTIC OIL PRODUCTION: ACTUAL THROUGH 1974 AND PROJECTED THROUGH 2020



Alaskan North Slope Oil: Completion of the TransAlaskan pipeline will result in an additional two million barrels of oil per day (maximum) arriving in the coterminous states. This represents approximately 25 percent of our current domestic oil production, which has dropped to about 8 million barrels per day.

Enhanced Recovery: On the average, about 32 percent of the oil in an underground deposit is recovered by pumping and/or natural flow. Thus, more than 2/3 of our domestic oil reserves are currently unavailable. Numerous techniques have been tested and some have been implemented to enhance the recovery of this oil. The figure suggests that such techniques may account for 33 percent of our total domestic production by 2020.

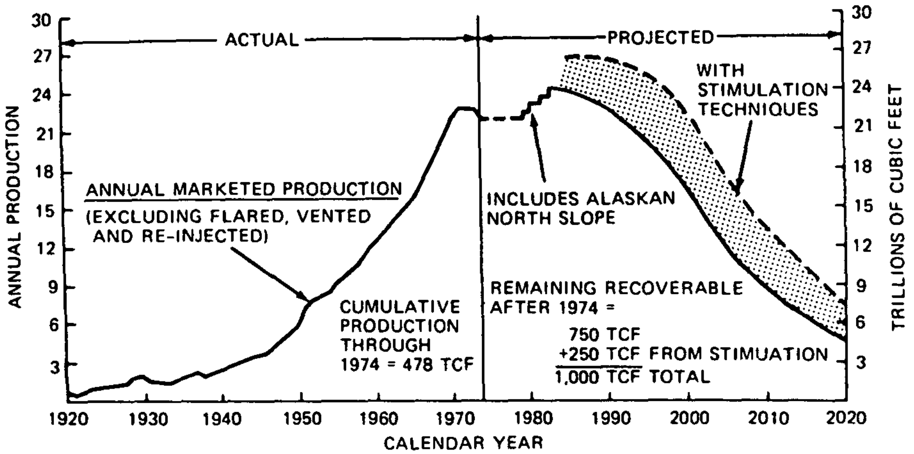
Current oil consumption is approximately 6 billion barrels of oil per year. Thus, 182 billion barrels of recoverable oil resources represent about 30 years supply at current demand. However, proven crude oil reserves of 34.3 billion barrels (COMMODITY DATA-1976, *supra* note 15, at 123) represent about 6 years supply at current demand.

While these projections are for domestic production of petroleum and natural gas, it is also necessary to consider our consumption of petroleum and petroleum products supplied by imports. Table II[22] and Table III[23] show projections for the sources of supply of our energy for 1980 and 1985.

22. DUPREE & CORSENTINO, *supra* note 18, at 11.
23. *Id.* at 10.

FIGURE 3

DOMESTIC NATURAL GAS PRODUCTION: ACTUAL THROUGH 1974 AND PROJECTED THROUGH 2020



TCF = trillion cubic feet.

Some gas from producing wells was either vented to the atmosphere, burned at the well head (flared) or reinjected into the well for later recovery.

Only about 70 to 80 percent of the gas in a well is recovered by natural flow and pumping. Techniques are being developed to stimulate increased flow from gas wells.

Current production is approximately 20 TCF/yr. Resources recoverable are 1000 TCF, therefore approximately 50 years supply, at current demand, remains; however (proven) reserves of 237 TCF (COMMODITY DATA-1976, *supra* note 15, at 109) represent only about 12 years supply at current production.

Data for per capita energy consumption in the United States are given in Table IV.[24] Even if, as a result of energy conservation, the per capita consumption of energy were not to increase as expected,[25] or to increase at less than the expected rate, since the United States population will also continue to increase,[26] our total consumption of energy will increase by 1985 as shown in Table III.

Since the 1973 oil embargo, the United States energy situation has been the subject of numerous reviews and studies.[27] Many as-

24. DUPREE & CORSENTINO, *supra* note 18, at 3 (for year 1974); ENERGY PERSPECTIVES, *supra* note 2, at 42 (for all other years).

25. DUPREE & CORSENTINO, *supra* note 18, at 6.

26. *Id.*

27. *See, e.g.*, DUPREE & CORSENTINO, *supra* note 18; ERDA-48, *supra* note 20; FEDERAL ENERGY ADMINISTRATION, NATIONAL ENERGY OUTLOOK, FEBRUARY, 1976 (1976) [hereinafter cited as FEA-76]; H. FRANSSEN, TOWARDS ENERGY INTERDEPENDENCE: ENERGY IN THE COMING DECADE (1975); NATIONAL ACADEMY OF ENGINEERING, U.S. ENERGY PROSPECTS: AN ENGINEERING VIEWPOINT (1974) [hereinafter cited as NAE-74]; Address by Linden, "MCF's, Megawatts and Myths," 57th Annual Meeting of the American Gas Association, Oct. 5-8, 1975 [hereinafter cited as Linden].

TABLE II

LIQUID HYDROCARBON SUPPLY, 1974-1985

Source	1974	1980	1985
Domestic Conventional Supply (Quads)	21.1	24.0	29.3
Percent of Total (%)	62.9	58.6	63.4
Synthetic Liquids (Quads)	—	—	0.61
Percent of Total (%)	—	—	1.3
Supplemental Supplies (Quads)*	12.4	17.0	16.3
Percent of Total (%)**	37.1	41.4	35.3
TOTAL (Quads)	33.5	41.0	46.2

*Supplemental supplies, as projected, are all imports and will remain imports unless the federal government intervenes to stimulate production of shale oil and liquefaction of coal more than is foreseen.

**During March 1976, imports (at least temporarily) exceeded domestic production.

TABLE III

U.S. GROSS ENERGY INPUTS BY SOURCE, 1974-1985
(Quads)

	1974	1980	1985
Coal	13.2	17.2	21.3
Petroleum	33.5	41.0	45.6
Natural Gas	22.2	20.6	20.1
Oil Shale	—	—	0.87
Nuclear Power	1.17	4.55	11.8
Hydropower and Geothermal	3.05	3.80	3.85
TOTAL	73.1	87.1	103.5

TABLE IV

U.S. ENERGY CONSUMPTION PER CAPITA, 1850-1974
(Millions of Btu)*

Year	Amount
1850	101.2
1860	100.4
1870	99.0
1880	99.4
1890	111.1
1900	125.9
1910	174.3
1920	200.1
1930	188.6
1940	189.5
1950	231.7
1960	246.6
1970	329.3
1971	333.4
1972	344.6
1973	355.1
1974	345

*100 million Btu ≈ 18 barrels of petroleum equivalent.

pects of this picture are changing, almost on a daily basis, and it is more difficult than usual to make projections, but the projections from these several studies are in good agreement. For the purpose of this discussion we shall take as our estimate for 1985, a total United States energy consumption of 104 Quads.[28]

Table II shows the relationship between domestic and imported supplies of petroleum hydrocarbon liquids as projected for the next decade. While these projections show the *percent* of petroleum imports to be essentially constant over the next decade (after maximizing around 1980), when viewed in light of the substantial increase in the *quantity* of petroleum necessary to meet our projected demands, it is obvious that the existing heavy dependence on petroleum imports will continue for at least the next decade.

Concurrent with this increase in petroleum usage, annual coal production will also increase very significantly in the next decade —probably to the point where it will provide a larger percentage of our total energy consumption than at present, as shown in Table III. The coal reserves are available, the need for increased production is apparent, and any likely increase in the cost of producing coal will not be out of line vis-à-vis the price of other fuels. The data given in Table III indicate that coal production is expected to increase by about 60 percent in terms of energy and will furnish about 21 percent of the total United States energy supply in 1985, as compared to 18 percent at present. Given the ample coal resources available in our country, and with our desire not to rely so heavily on fuel imports, petroleum in particular, is it possible for coal to make an even larger percentage contribution to our energy supplies by 1985? Considering only the factors of resources and demand, the answer would be yes. However, there are other significant factors—technological, governmental, economic and environmental—that are associated with increasing coal production beyond that projected above. The interplay of these factors, and others, makes the answering of the above question very difficult. A discussion of these interactions and their impact on attempts to increase coal production and utilization follows.

28. DUPREE & CORSENTINO, *supra* note 18, at 5.

II. INCREASING COAL PRODUCTION

In its study published in 1974, the Task Force on Energy of the National Academy of Engineering[29] (NAE) projected annual coal production in 1985 to be 1260 million tons. They compared production for 1973 with that projected for 1985 in terms of Eastern versus Western mines, and underground versus surface (strip) mines.

TABLE V

NATIONAL ACADEMY OF ENGINEERING ESTIMATES FOR COAL PRODUCTION IN 1985

MILLIONS OF TONS PER YEAR (MTPY)

Mine Type	1973 Production	Additions 1974-1985	Depletions 1974-1985	1985 Estimate
Eastern Underground	300	280	100	480
Eastern Surface	240	60	80	220
Western Surface	60	520	20	560
TOTAL	600	860	200	1,260*

*This total "Estimated Production for 1985" includes 310 MTPY of coal to be used to produce 1.7 million barrels oil equivalent of synthetic fuels. See text for a revision of this 1985 estimate.

As Table V[30] indicates, this projection sees coal production doubling in the next decade, most significantly from expansion of surface mining in the Western United States. Thus, if production of Western coals were to increase tenfold, Eastern underground production need only increase by about a factor of 1.6, and together both could absorb the small projected decrease in Eastern surface mining and still result in a net doubling of total coal production.

Paramount in the Task Force's rationale for these projections is the nature of the existing seams of Western coals. While Eastern coal seams are rarely thicker than 6 feet and frequently under hundreds of feet of overburden (thus the need for underground mining), many Western seams are much thicker (50-75 feet) and much nearer the surface (30-40 feet of overburden).[31] In addition, Western coals have some properties that make their subsequent utilization

29. NAE-74, *supra* note 27.

30. *Id.* at 34.

31. Atwood, *The Strip-Mining of Western Coal*, 233 SCIENTIFIC AMERICAN, Dec. 1975, at 23 [hereinafter cited as Atwood]. *See also* the references cited therein. For a dramatic pictorial presentation of the differences between Eastern underground mining and Western surface mining, see Young & Blair, *Will Coal Be Tomorrow's "Black Gold"*?, 148 NATIONAL GEOGRAPHIC, No. 2, Aug. 1975, at 234.

desirable. For example, Western coals are generally lower in sulfur content, which is important in environmental considerations.[32] Economic factors also indicate that substantial increases in production of Western coals will occur because of the higher productivity per man-day[33] and the greater efficiency of recovery in strip mining operations.

To grasp the magnitude of increasing production to these levels, the following is a list from the NAE report of the number and type of facilities that would have to be developed to meet their projection:

- Develop 140 new 2 Million Ton Per Year (MTPY) Eastern underground mines.
- Develop 30 new 2-MTPY Eastern surface mines.
- Develop 100 new 5-MTPY Western surface mines.
- Recruit and train 80,000 new Eastern coal miners.
- Recruit and train 45,000 new Western coal miners.
- Manufacture [and install] 140 new 100-cubic-yard shovels and draglines.
- Manufacture 2,400 continuous mining machines.

> Stated another way, on the average one new deep mine and one new surface mine must be brought into production every month for 10 years. In contrast, only 13 mines of greater than 2-MTPY production were opened in the 10 years from 1960 to 1969. In 1971, there were only 25 mines operating that were larger than 2 MTPY and only 3 of these exceeded 5 MTPY.[34]

A recent federal report on synthetic fuels commercialization[35] estimated that synthetic fuels production from coal and oil shale would be only in the range of 350,000 to one million barrels of oil equivalent per day (BOED) by 1985.[36] For our estimates, we shall assume that synthetic fuel production in 1985 will be 700,000 BOED and that

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32. *See* R. THOMSON & H. YORK, THE RESERVE BASE OF U.S. COALS BY SULFUR CONTENT, PART 1: THE EASTERN STATES (1975) (BOM I.C. 8680) [hereinafter cited as THOMSON & YORK]; P. HAMILTON, D. WHITE, JR., & T. MATSON, THE RESERVE BASE OF U.S. COALS BY SULFUR CONTENT, PART 2: THE WESTERN STATES (1975) (BOM I.C. 8693) [hereinafter cited as HAMILTON, WHITE & MATSON].

33. *See* text accompanying TABLE VII *infra*.

34. NAE-74, *supra* note 27, at 35.

35. 1-4 SYNFUELS INTERAGENCY TASK FORCE, RECOMMENDATIONS FOR A SYNTHETIC FUELS COMMERCIALIZATION PROGRAM (1975) [hereinafter cited as SYNFUELS].

36. 1 SYNFUELS, *supra* note 35, at 69.

half of this will be from coal. As noted in Table V, the National Academy of Engineering estimated that 310 MTPY of coal production would be needed to produce 1.7 million BOED of synthetic fuels. If only 350,000 BOED will be produced from coal, then only (0.35/1.7) x 310 = 64 MTPY of coal will be needed for synfuels production. Thus, we can (and should) lower the NAE estimate for total coal production in 1985 to approximately 1014 MTPY.

Several other recent estimates for 1985 coal production have been made. As part of its projection for a United States energy consumption of 104 Quads, the United States Bureau of Mines estimates total coal production in 1985 at 998 MTPY.[37] The Federal Energy Administration in its latest report on the national energy outlook estimates United States energy consumption in 1985 to be 99 Quads[38] and total coal production to be 1040 MTPY, including exports of 80 MTPY.[39] It has been recently estimated that in 1985, United States energy consumption will be about 100 Quads and total coal production will be "920-970 MTPY if we allow for 100 MTPY of exports and roughly 70 MTPY (used) to produce a modest one Quad [approximately 500,000 BOED] of synthetic fuels."[40] When one considers the number of variables that must be taken into account in making any projection of this type, these estimates are in good agreement.[41]

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37. DUPREE & CORSENTINO, *supra* note 18, at 61. This production figure includes 75 MTPY for export.

38. FEA-76, *supra* note 27, at 16.

39. *Id.* at 21.

40. Linden, *supra* note 27.

41. DUPREE & CORSENTINO, *supra* note 18, discuss the methodology used in their forecast:

> The future energy requirements forecast in this paper were based upon a variety of forecasting techniques and the personal judgments of energy specialists in the Bureau of Mines. Gross national product, population, manufacturing value added, and other basic economic data were correlated with energy consumption, and any important and consistent trends were extrapolated. This was true of both overall energy consumption and individual energy consumption in the three end use sectors [industrial, household/commercial, transportation].
>
> Once total and sectorial energy consumption were established, the sources of the energy were determined. At that point, supply constraints were recognized, and the secondary sources of energy factored into the forecast. Projection of energy supplies were made, and then the projections of energy use and supplies were reconciled.
>
> It must be stressed that this is essentially a judgmental projection of future energy consumption.

Id. at 26. The authors also stated:

> The potentials for conservation were not explicitly factored into the base forecast. The role of conservation in reducing future energy consumption is not well defined.

Thus, for the purposes of this discussion, an estimate of 1000 MTPY coal production in 1985 is reasonable. Even if this estimate is off in either direction by 50 MTPY, the number of new mines, new miners and new equipment that will be needed represents a major effort on the part of American industry. As alluded to earlier, many factors will determine if this estimated production of 1000 MTPY will be reached. As one example, the National Academy of Engineering projected that to meet its estimate of increased coal production approximately $21 billion in capital expenditures by industry would be necessary.[42]

Transportation is one area where technological and logistical factors become important. All estimates project the largest increase in production to be with Western coal. At the same time, the primary users of coal are in the East and therefore transportation of the huge quantities of Western coals to be mined necessitates a corresponding increase in transportation facilities. Railroad, water barge, and coal slurry pipeline facilities must all be vastly increased to move the coal over distances as great as 1500 miles. This is discussed in the Academy's report in some detail.[43]

Coal production from surface mining both today and in the future will include land reclamation. Reclamation can and is being done throughout the country. However, in the West, it is often more difficult and expensive because of problems such as climate, geology and hydrology.[44] Further, the interaction between state and federal authorities and the coal producers in regard to land leasing and reclamation standards will be of prime importance in this area. This question was of concern in President Ford's Energy Message to Congress, where it was noted:

> Many promising areas are being explored, but the economic, resource, and political impacts have not been outlined to the point where a reasonable scenario can be developed. Complicating the picture is the nonadditive nature of many of the potential savings. This should not be interpreted to mean that energy conservation was neglected . . . . It should be noted that these [energy conservation measures] will probably represent more a response to energy price increases than to governmental action.

Id.

42. NAE-74, *supra* note 27, at 35.

43. *Id.* at 36.

44. *See* Atwood, *supra* note 31. *See also* F. PERSE, U.S. BUREAU OF MINES, DEP'T OF THE INTERIOR, STRIP-MINING TECHNIQUES TO MINIMIZE ENVIRONMENTAL DAMAGE IN THE UPPER MISSOURI RIVER BASIN STATES (1975) (BOM I.C. 8685).

> The Secretary of the Interior has recently adopted a new coal leasing policy for the leasing and development of more coal on Federal lands. To implement this policy, regulations will be issued governing coal mining operations on Federal lands, providing for timely development, and requiring effective surface mining controls which will minimize adverse environmental impacts and require that mined lands be reclaimed. As a reflection of the States' interests, the Department proposes to allow application on Federal lands of State coal mine reclamation standards which are more stringent than Federal standards, unless overriding National interests are involved.[45]

Some insight into the magnitude of the involvement of the federal government in this area can be gained by examining the data on the percent of coal lands and coal rights in the Western states owned by the federal government, given in Table VI.[46]

The availability of water for coal production and utilization, particularly in the West, is another critical technological factor. Every aspect of energy production—mining, electric power generation, synthetic fuels production, etc.—will be affected by the supply of water. A recent report by the United States Bureau of Reclamation of the Department of the Interior discusses in detail the question of water availability in eleven Western states.[47] The report summarizes the scope of this problem and points out that water for energy resource development is only part of the overall problem:

> The major water and related resource problems and issues of the 11 Western States are, in general, common to all 11 States, differing only in extent or degree of seriousness. The Westwide Study effort identified a number of such problems and issues, some of which overlap. They fall into four broad categories—water supply, water quality, environmental, and other.
>
> The water supply problems include: water for energy resource development, water for small communities, water for Indian reservations, water for public lands, water from conservation and reuse, and water from weather modification. The water quality problems cover: water pollution and urban waste

45. The President's Energy Message to the Congress of the United States, Feb. 26, 1976, *as quoted in* 12 WEEKLY COMPILATION OF PRESIDENTIAL DOCUMENTS 292 (1976).

46. AVERITT, *supra* note 11, at 14-15, 88; U.S. BUREAU OF RECLAMATION, DEP'T OF THE INTERIOR, WESTWIDE STUDY REPORT ON CRITICAL WATER PROBLEMS FACING THE ELEVEN WESTERN STATES 58-79 (1975) [hereinafter cited as WESTWIDE STUDY].

47. WESTWIDE STUDY, *supra* note 46.

TABLE VI

WATER AND COAL IN 11 WESTERN STATES

Availability of Water*	State	Coal Reserves, Millions of Tons**	U.S. Identified Resources (percent) d	Federal Ownership (percent)***	Comments
	Arizona	21,234	1.2	small	
Critically	Nevada	—	—	nr	
Short	Wyoming	135,943	7.9	65	a
	Montana	291,639	16.9	75	b
Limited—	California	—	—	nr	
Other Uses	Colorado	128,948	7.5	53	a
Will Grow	New Mexico	61,391	3.6	59	
	Utah	23,359	1.4	82	a
	Idaho	—	—	nr	c
Abundant	Oregon	334	.02	nr	
	Washington	6,169	.36	nr	

*Data from WESTWIDE STUDY, *supra* note 46, at 58-79.
**Data from AVERITT, *supra* note 11, at 14-15. Averitt lists these as "Identified resources."
***Data from AVERITT, *supra* note 11, at 88.
nr=not reported.
a—These states also contain large deposits of oil shale. The production of oil from oil shale or liquefaction of coal and gas from gasification of coal require about the same quantity of water on a per Btu of fuel produced basis.
b—There is sufficient water, but the water and coal are in different regions of the state.
c—Coal from Wyoming or Montana could be imported to take advantage of available water.
d—These 11 states possess 38.7 percent of the total United States identified resources.

water management, increasing salinity in major river systems, and erosion and sedimentation. Environmental problems encompass: the environmental data gap; wild, scenic, and recreational rivers; wilderness areas; and flat water recreation. The other problems relate to: Federal assistance to irrigation development, coordinated land and water use planning, and flood plain management.[48]

We have grouped the eleven Western states by availability of water in Table VI and also indicated the size of identified coal resources in each state. Three states, Colorado, New Mexico and Utah, have significant identified coal resources (12.5 percent of our total identified resources) but only enough water to meet current demands. Thus, projects to increase coal production and utilization will have to compete for available water with the expansion of al-

48. *Id.* at 9.

ready existing uses. Finally, approximately 9 percent of our total identified coal resources are in states where water is already in critically short supply.

There are other technological factors closer to the theme of this symposium that are also important. The Federal Coal Mine Health and Safety Act of 1969[49] sets out an extensive list of health and safety standards with which all coal mine operators must comply. These include maximum permissible levels of respirable dust, noise, toxic and explosive gases;[50] methods of roof support in underground mines;[51] minimum fire protection equipment;[52] and permissible electrical equipment and its maintenance.[53] The implementation of these standards is designed to improve health and safety conditions in coal mines.

Without arguing the relative merits of the Act generally or any of its provisions specifically, it is important to realize that from a technical point of view there are problems in meeting the established standards. A recent report to the Congress by the Comptroller General[54] takes note of these problems:

> Department of the Interior officials, mine operators, miners, and union officials agree that significant improvements have been made in reducing the amounts of coal dust in mines since the Mining Enforcement and Safety Administration's respirable coal dust sampling program was begun in 1970. Respirable coal dust may cause a type of pneumoconiosis commonly known as "black lung" disease.
>
> Even so, GAO [General Accounting Office] noted many weaknesses in the dust-sampling program which affected the *accuracy* and *validity* of the results and made it virtually impossible to determine how many mine sections were in compliance with statutorily established dust standards.
>
> The uncertainty of the dust-sampling equipments' accuracy, improper or inadequate procedures followed by operators and miners taking the samples, and cassette weighing errors make, in GAO's view, current dust measurements unreliable, al-

49. 30 U.S.C. §§ 801-960 (1970), *as amended* (Supp. V, 1975).
50. *Id.* §§ 842, 846, 863.
51. *Id.* § 862.
52. *Id.* § 871.
53. *Id.* §§ 865, 867-69.
54. U.S. General Accounting Office, Improvements Still Needed in Coal Mine Dust-Sampling Program and Penalty Assessments and Collections (1975).

though the Mining Enforcement and Safety Administration has informed GAO that a cassette weight loss problem has been corrected . . . .

. . . .

During our review, we accompanied MESA [Mining Enforcement and Safety Administration] inspectors to 14 mines and observed 22 miners taking dust samples; some of the miners' practices did not comply with the required sampling procedures . . . .

. . . [W]e observed [at least one] improper sampling [procedure] at every one of the 14 mines we visited . . . .

. . . .

GAO recommends that the Secretaries of the Interior and Health, Education, and Welfare make further improvements in the dust-sampling equipment including the improvements recommended in a December 1975 report by the National Bureau of Standards such as flow rate regulators, alternate timing devices, more rugged components, and tamper-proof cassettes.[55]

The above is a good example of the fact that any individual involved with data collection must always be concerned with the accuracy, precision and validity of his procedures so as to increase the probability of meaningful results. But at the same time, it should be obvious that following strict laboratory procedures for a given analysis is not always possible outside the laboratory, particularly in an environment such as a coal mine.

While the above discussion refers to the problems associated with determining compliance with an established standard, a potentially more difficult problem surrounds the actual establishment of the standard in the first place. Some parameters are such that the standards can be based directly on scientific experimentation in the laboratory and then reliably applied in the field. For example, the different ratios of methane gas in air which form explosive mixtures have been determined by laboratory experimentation. This scientific data, when combined with appropriate safety limits, has been used to promulgate standards for permissable methane levels in a mine, such that if the standard is exceeded, mining operations must cease. Unfortunately, hard scientific evidence does not exist for all established standards. The respirable coal dust problem referred to

55. *Id.* at i, 17-18 (emphasis added).

before is such a standard. A quantitative relationship between respirable coal dust and coal miners' pneumoconiosis has not been established. The standardization of what quantities (with appropriate safety limits) of coal dust can be tolerated in a mine without endangering the health and safety of the miners is an extremely difficult task.

We do not argue that, because of the lack of hard scientific evidence, no standard should be established. Presumptively all of the standards were established on the best available evidence, but in light of the matters discussed previously, experimentation should continue so that standards as objective as possible can be employed.

The standards of the Coal Mine Health and Safety Act impact most strongly on the operation of underground mines. The productivity data given in Table VII[56] reflect, at least in part, the impact of this Act.

After increasing steadily, productivity in underground mines peaked in 1969 at 15.6 short tons[57] per man-day and then decreased in each succeeding year to a level of 11.7 short tons per man-day in 1973. This amounts to a net decrease in productivity of 25 percent. In contrast, surface mine productivity, which is much higher anyway, increased slightly over the same time period.

Total bituminous coal production from underground mines decreased between 1969 and 1973 by 14 percent which was paralleled by a decrease in the number of underground mines of 44 percent. By contrast, over the same time period, production from surface mines increased by 38 percent and the number of surface mines increased by 49 percent. Also of note is that since 1971 as much coal has been produced from surface mines as from underground mines. Coal production in 1974 (bituminous and lignite) was 604 million tons, and 1975 production was 637 million tons.[58] The largest previous production was in 1947 when 631 million tons of bituminous coal and lignite were mined.[59]

Partly as a result of the decrease in productivity, the average price

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56. *E.g.*, U.S. BUREAU OF MINES, DEP'T OF THE INTERIOR, MINERALS YEARBOOK (1973). Such a yearbook typically summarizes production and productivity data for the previous four years as well as the current year. The entries in TABLE VII were generated by the authors from data provided in many different tables in the yearbooks for the years 1965-1973.

57. A short ton is 2000 pounds.

58. COMMODITY DATA-1976, *supra* note 15, at 40.

59. U.S. BUREAU OF MINES, DEP'T OF THE INTERIOR, MINERALS YEARBOOK (1947).

TABLE VII

DATA FOR THE U.S. COAL INDUSTRY ON
NUMBER OF MINES, PRODUCTION, PRODUCTIVITY AND COST OF COAL—1965-1973

	1965	1966	1967	1968	1969	1970	1971	1972	1973
Number of Mines									
Underground	5,280	4,741	3,908	3,381	3,097	2,939	2,268	1,996	1,737
Strip*	1,541	1,572	1,507	1,492	1,551	2,103	2,290	2,309	2,309
Auger*	407	436	458	454	470	559	591	574	698
TOTAL***	7,228	6,749	5,873	5,327	5,118	5,601	5,149	4,879	4,744
*Production, Millions of Short Tons***									
Underground	333	339	349	344	347	339	276	304	299
Strip	165	180	187	186	197	244	259	276	277
Auger	14	15	16	15	16	20	17	16	16
TOTAL***	512	534	552	545	561	603	552	595	592
Productivity—Short Tons Per Man-Day									
Underground	14.00	14.64	15.07	15.40	15.61	13.76	12.03	11.91	11.66
Strip	31.98	33.57	35.17	34.24	35.71	35.96	35.69	35.95	36.30
Auger	45.85	44.43	46.48	40.46	39.88	34.26	39.00	43.00	45.33
WEIGHTED AVERAGE	17.52	18.52	19.17	19.37	19.90	18.84	18.02	17.74	17.58
Cost, Dollars Per Ton, f.o.b. Mine									
Underground	4.93	5.05	5.18	5.22	5.62	7.40	8.87	9.70	10.84
Strip	3.57	3.64	3.68	3.75	3.98	4.69	5.19	5.48	6.11
Auger	3.36	3.58	3.59	3.53	3.81	6.08	6.57	6.54	7.39
WEIGHTED AVERAGE	4.44	4.54	4.62	4.67	4.99	6.26	7.07	7.66	8.53

*Strip mining and auger mining are the two types of surface mining practiced in the United States today.

**These figures do not include the data for Pennsylvania anthracite production which is about 6 million tons per year or about 1 percent of the bituminous coal and lignite production.

***Data may not add to totals shown because of independent rounding of numbers of coal from underground mines increased by 93 percent during the period 1969 to 1973, as compared to increases of 54 and 94 percent for strip and auger-mined coal, respectively, over the same time period. As a point of interest, in 1975 the average cost of all coal, was about $17.50 per ton, compared to $15.75 in 1974 and $8.53 in 1973.[60] The average price per barrel of domestic crude oil was about $8.00 in 1975 compared to $6.74 in 1974 and $3.89 in 1973.[61]

The decline in productivity in underground coal mines is of great concern to the coal industry. Unless the productivity in underground mines can be raised significantly, it will act as a severe constraint on increasing coal production. In a recent report issued by the Battelle Columbus Laboratories this point is underscored:

> Part of the 1969-1974 decline in productivity is obviously assignable to the many additional underground support tasks that are now required concerning ventilation, roof support, methane and dust control, and training. Although such functions are not always as directly involved with production as is the operation of a continuous miner, they are vital to the system and "productive" in the total system sense. Industry wide, from 1960 to 1973, over 20,000 additional inexperienced employees became involved in production. This represents a 20 percent increase, a large portion of which enters into the input portion of the productivity computation. An analogous increment of new personnel will be recruited to support the new helper requirements and the 90-day orientation requirements of the 1974 UMWA-BCOA contract. It should not be a surprise if the productivity trend down were to continue.[62]

The country's goal is to increase coal production significantly in the next decade. Increasing productivity in coal mines is obviously one way to achieve this goal, but for underground mines this may not be possible. Another approach will be to simply take advantage of the much higher productivity of surface mines and to open new surface mines, particularly in the Western states. But as we have discussed earlier, the questions of transporting Western coal (or electricity generated in plants near the source of the coal) to its

60. U.S. BUREAU OF MINES, DEP'T OF THE INTERIOR, MINERALS AND MATERIALS/A MONTHLY SURVEY, Feb. 1976, at 15.

61. *Id.* at 11.

62. 1 BATTELLE COLUMBUS LABORATORIES, A SYSTEMS APPROACH TO UNDERGROUND COAL MINING: PHASE I—PROBLEM ANALYSIS AND RESEARCH RECOMMENDATIONS 41 (1975).

point of use, the ability to reclaim strip-mined lands and the cost involved, and the availability of water in the Western states, will all affect the production levels attained.

III. Increasing Coal Utilization

In 1974, most of the coal produced in this country (63.5 percent) was used to generate electricity.[63] Coal was also used for the production of coke and gas (14.8 percent), for industrial heating (10.3 percent), for residential and commercial heating (1.8 percent), and for export (9.6 percent).[64] If the production of coal increases to the projections noted before,[65] how will the additional supply be utilized?

Table VIII[66] shows projected values for 1985 coal consumption.

Table VIII

1974 Coal Consumption and Values Projected for 1985

Millions of Tons Per Year (MTPY)

	1974	1985
Electric Utilities	388	715
Industrial	64	124
Coke and Gas	90	100
Household/Commercial	9	5
Synthetic Fuels	—	16
Export	60	80
Total	611	1040

Most of the projected increase will be used for the generation of electricity. Installed electrical generating capacity is expected to almost double in the next decade—from 475 gigawatts in 1974 to approximately 900 gigawatts by 1985.[67] Even though nuclear power is expected to contribute substantially to our energy supply by 1985 as shown in Table III, coal is still expected to produce about 40

63. Dupree & Corsentino, *supra* note 18, at 61. The energy for all electricity generation was supplied by the various sources in the following proportions: coal—44.1 percent, natural gas—16.9 percent, petroleum products—17.6 percent, nuclear power—6.0 percent, and hydropower and geothermal—15.4 percent. *Id.* at 36, 38.

64. *Id.* at 61.

65. *See* text at 562 *supra*.

66. FEA-76, *supra* note 27, at 175.

67. Dupree & Corsentino, *supra* note 18, at 40. One gigawatt is one billion watts. A typical modern electric power plant is one gigawatt (1000 megawatts or 1,000,000 kilowatts).

percent of the electricity generated in 1985; oil and natural gas will produce about 19.7 percent.[68]

Some electrical generating plants presently fired with oil or natural gas could be converted to coal-fired plants, and thus either preserve the supplies of these more scarce fuels or divert them to other and more valuable uses, such as the production of petrochemicals. Congressional desire to have power plants and industrial furnaces presently fired with oil or gas converted to coal-burning plants is reflected in the Energy Supply and Environmental Coordination Act of 1974[69] and the Energy Policy and Conservation Act of 1975.[70] Together these Acts provide that the Federal Energy Administration (FEA) must prohibit power plants (and may prohibit other major fuel burning installations) from using oil or gas if (1) conversion to coal is practicable, (2) coal will be available and (3) reliability of operation of electric power plants will not be impaired.[71] Obviously, the point of this conversion-to-coal is to save oil and gas now, wherever possible. However, an FEA order to undertake such a conversion does not become effective until the Environmental Protection Agency (EPA) determines that the plant can comply with EPA-imposed air pollution standards, promulgated pursuant to the Clean Air Act as amended in 1970. In all cases, a source is not to proceed to convert to coal until the EPA approves a schedule under which the source must comply with emission requirements as soon as practicable, but no later than January 1, 1979.[72] Further, the Federal Energy Administration is required to comply with the provisions of the National Environmental Policy Act for any prohibitions lasting longer than one year.[73]

The Clean Air Act as amended[74] requires that the EPA establish national air quality standards as well as emission standards for significant new pollution sources and for all facilities emitting hazardous substances. The Act also establishes a framework for the states to set emission standards for existing sources in order to

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68. *Id.* at 36, 38.

69. Pub. L. No. 93-319, 88 Stat. 246 (codified at 15 U.S.C. §§ 791-98 (Supp. IV, 1974), *as amended* (Supp. V, 1975) and in scattered sections of 42 U.S.C.).

70. Pub. L. No. 94-163, 89 Stat. 871 (amending scattered sections of 15, 42 U.S.C. and adding 42 U.S.C. §§ 6201-6422 (Supp. V, 1975)).

71. 15 U.S.C. § 792 (Supp. V, 1975).

72. 42 U.S.C. § 1857c-10 (Supp. V, 1975).

73. 15 U.S.C. § 793(c)(2) (Supp. V, 1975).

74. 42 U.S.C. §§ 1857-57*l* (1970), *as amended* (Supp. V, 1975).

achieve the national air quality standards.[75] Implementation plans for the states, which may call for standards stricter than the national standards, are subject to EPA approval.[76] If a state plan is considered inadequate, the EPA may impose a plan of its own that will take precedence.[77] National ambient air quality standards were set for SO_2 emissions in 1971 by the EPA.[78] States have established various SO_2 emission limitations for pollution sources so as to meet the ambient air standards. The Act requires enforcement of state implementation plans (SIP's) for SO_2 emission controls in mid-1975, but deferrals are allowed to 1977.[79] Congress is presently considering several proposals to amend this legislation.[80]

The provisions of these Acts are not in conflict, for the conversion to coal can only be mandated if and when the established emission standards can be met. At the same time, the underlying policy of each Act when integrated with our existing technology creates a dilemma. The policy of the Clean Air Act is to improve the quality of our air resources.[81] This directly affects present and prospective coal production and utilization in that coals with too high a sulfur content may not be burned, because upon combustion they produce too much of the air pollutant sulfur dioxide (SO_2). *If these coals cannot be used, they will not be mined.* Thus, production will be that much lower, and either other cleaner fuels must be substituted for the high-sulfur coal, which would be contrary to the policy of the Energy Supply and Environmental Coordination Act and the Energy Policy and Conservation Act,[82] or we must do without the electricity and power that would have been generated. Thus, the technological problem is to implement a method or methods whereby coal can be the source of the energy used in electricity production

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75. *Id.* § 1857c-5.

76. *Id.*

77. *Id.*

78. 40 C.F.R. §§ 50.4, .5 (1975).

79. 42 U.S.C. § 1857c-5 (1970), *as amended* (Supp. V, 1975).

80. *See* Rosenblum, *The Future of the Coal Substitution Option*, 14 DUQ. L. REV. 581, 618-19 (1976); Snyder & Worthen, *Coal Conversion and Amendments to the Clean Air Act*, 14 DUQ. L. REV. 623, 635-36 (1976).

81. 42 U.S.C. § 1857 (Supp. V, 1975) provides: "The purposes of this title are . . . to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population . . . ."

82. 42 U.S.C. § 6201 (Supp. V, 1975) provides: "The purposes of this Act are . . . to reduce the demand for petroleum products and natural gas through programs designed to provide greater availability and use of this Nation's abundant coal resources . . . ."

in such a manner that no deleterious impact upon the environment occurs. This would involve the use of low sulfur coals or the removal of SO_2 from coal combustion products or a combination of these technologies. If these technologies can be implemented, the policies of the Acts can be furthered.

In order to examine the magnitude of this technological problem it is necessary to briefly review the SO_2 emission standards set by the EPA. In an effort to achieve primary (and secondary) ambient air quality standards,[83] the EPA has adopted a national standard for SO_2 emissions of 1.2 pounds of SO_2 per million Btu of heat input for each "new" (*i.e.*, installation commenced after August 1971) coal-fired stationary source.[84] This is the "new source performance standard" (NSPS). Sulfur dioxide emission limits are stated in terms of energy input rather than pounds of fuel used, since there is a large range of Btu values for coals and thus, this distinction is important.

TABLE IX

MAXIMUM ALLOWABLE SULFUR CONTENT OF COAL REQUIRED TO MEET SULFUR OXIDE EMISSION STANDARDS IN COALS OF DIFFERENT BTU CONTENT

Various Emission Standards (lbs. SO_2 per million Btu)		% S Meeting the SO_2 Emission Standard* for a Coal Whose Btu Content (in Btu per lb.) is:			
	Btu/lb.	8,000	10,000	12,000	14,000
0.6		0.24	0.30	0.36	0.42
1.2**		0.48	0.60	0.72	0.84
2.4		0.96	1.20	1.44	1.68
4.8		1.92	2.40	2.88	3.36

*Assumes all sulfur is converted into SO_2. The fact that some sulfur remains in the ash (about 5 percent) would raise these entries by a comparable amount.
**Existing New Source Performance Standard.

Table IX[85] lists the maximum sulfur content of coals of various Btu content which may be burned and not exceed the indicated SO_2 emission limits without the use of additional emission control technologies. Most of the coal presently being burned in electrical utili-

83. Primary ambient air quality standards were set for the purpose of protecting public health. Secondary ambient air quality standards were set to protect public welfare, and are more stringent than primary standards.

84. 40 C.F.R. § 60.43 (1975).

85. COMMERCE REPORT, *supra* note 10, at 12.

ties and industrial furnaces has too high a sulfur content to meet the NSPS. For example, an Eastern bituminous coal with a heating value of 14,000 Btu/lb typically contains approximately 2.5 percent sulfur.[86] With no control technologies, this results in SO_2 emissions three times the amount permissible under the NSPS. Indeed, there are Eastern coals with low enough sulfur levels to meet the NSPS; however, they are not a large percentage of the total reserves and most of these coals are of metallurgical quality and thus reserved to make coke for use in blast furnaces or for export.

The Bureau of Mines has compiled data on the amount of coal reserves available, as a function of their sulfur content.[87] East of the Mississippi River, the reserve base of low-sulfur coal (defined by the Bureau as coal containing one percent or less of sulfur) is 26.5 billion tons of bituminous coal and 6.3 billion tons of anthracite coal. West of the Mississippi River, the reserve base of low-sulfur coal is 167 billion tons of bituminous and subbituminous coals and lignite. The reserves of low-sulfur coal are much higher in the West, much of it can be strip-mined, and its cost will be lower than Eastern coal. These reasons explain the planned several-fold increase by 1985 in the production of Western coal referred to in Table V.

The sulfur content of high-sulfur coals can be reduced by either physical or chemical methods. The physical technique in wide commercial use is coal beneficiation (cleaning or washing).[88] This technique mechanically separates the denser mineral matter (in particular pyrite, FeS_2) from the less dense organic fraction of the coal. However, this process does *not* remove the sulfur chemically bonded to the organic fraction. Beneficiation thus will reduce the sulfur-to-Btu-content ratio and result in a more acceptable fuel. However, very few cleaned coals are sufficiently low in sulfur content to meet existing SO_2 emission standards.[89]

Chemical methods for removing sulfur from coal to produce a low-sulfur coal are under development, but are not yet not commercially available.[90] Also under intense development are chemical methods

86. THOMSON & YORK, *supra* note 32, at 5.

87. *See* THOMSON & YORK, *supra* note 32; HAMILTON, WHITE & MATSON, *supra* note 32.

88. *See, e.g.*, COAL PREPARATION (J. Leonard & D. Mitchell eds. 1968); A. DEURBROUCK, SULFUR REDUCTION POTENTIAL OF THE COALS OF THE UNITED STATES (1972) (BOM R.I. 7633).

89. THOMSON & YORK, *supra* note 32, at 534. Coal beneficiation was originally conceived of as a process to reduce the mineral matter content of coal and thus to diminish the amount of ash formed during coal combustion, not as a desulfurization process.

90. *See, e.g.*, Address by S. Friedman, "Chemical Removal of Pyrite," 1975 Engineering

for converting coal to low sulfur "synthetic" liquid and gaseous fuels. As shown in Table VIII and as discussed earlier, some production of synthetic fuels via coal conversion processes is expected by 1985, but not in significant amounts. Synthetic fuels, produced both from coal and oil shale, are expected to contribute significantly to our energy supplies by the year 2000,[91] and will be a source of clean (that is low in sulfur and ash) environmentally acceptable fuels to replace our dwindling supplies of petroleum and natural gas.

The chemical processing of coal to produce gaseous fuels is called coal gasification.[92] When used to produce liquid fuels, the process is called coal liquefaction.[93] In both cases, as indicated above, one aim of these coal conversion processes is to take a high-sulfur, high-ash, environmentally unacceptable coal and produce a low-sulfur, low-ash, more environmentally acceptable fuel from it. Another rationale for converting the solid fuel, coal, to liquid and gaseous fuels is that certain sectors of our economy require liquid fuels—for example, gasoline, diesel or jet fuels for internal combustion engines—or gaseous fuels, such as are used for residential and commercial heating and for certain industrial processing requirements. As indicated earlier, these use sectors consume a large fraction of our energy supplies, in particular petroleum and natural gas which will eventually be in short supply. In addition, the processing of coal via the formation of gases and liquids to produce chemical feedstocks (for plastics, fibers, drugs, solvents, etc.) will be important in partially replacing this use of petroleum and natural gas.

The basic physical and chemical principles involved in converting coal to liquids and gases are fairly well understood, though important details still remain under study.[94] However, the engineering

Foundation Conference, Aug. 12, 1975. *See also* Reggel, Raymond, Wender & Blaustein, *Preparation of Ash-Free, Pyrite-Free Coal by Mild Chemical Treatment*, 17 PREPRINTS DIVISION OF FUEL CHEMISTRY, AMERICAN CHEMICAL SOCIETY 44 (1972).

91. DUPREE & CORSENTINO, *supra* note 18, at 28.

92. *See* Perry, *The Gasification of Coal*, 230 SCIENTIFIC AMERICAN, Mar. 1974, at 19, and references cited therein. *See also* 2 COAL PROCESSING TECHNOLOGY (Chemical Engineering Progress ed. 1975) [hereinafter cited as COAL PROCESSING]. For an excellent, up-to-date review of the chemical processing of coal to produce gaseous and liquid fuels, see the collection of 43 papers in Institute of Gas Technology Symposium on Clean Fuels from Coal II, June 1975 [hereinafter cited as IGT-75].

93. *See* COAL PROCESSING, *supra* note 92. *See also* IGT-75, *supra* note 92.

94. Gasification of coal involves the reaction of coal with steam and oxygen (or air) in a gasifier at high temperatures to produce a mixture of gases—hydrogen, carbon monoxide, carbon dioxide, methane, unreacted steam, hydrogen sulfide and organic sulfur-containing

aspects of these processes, the so-called technological factors, are to a large extent still unresolved. Intense research and development work on coal conversion processes are being carried out in industrial, academic, and government laboratories, both in the United States and overseas.[95] But it is already apparent from an engineering point of view that the design, construction and operation of large-scale coal conversion facilities will be very formidable, very expensive and will require many years to accomplish. This is the primary reason that the projections indicate that only relatively small amounts of coal-derived synthetic fuels will be produced by 1985.

A coal-to-substitute natural gas plant capable of producing the equivalent in "clean" energy of 50,000 barrels of oil per day (*i.e.*, about 0.1 Quads of energy per year) would be a reasonable size facility for the "first generation" of such coal-conversion facilities. (Note that our projected total energy consumption in 1985 is about 100 Quads.) Recent estimates for the capital investment required for such a plant run to more than $500 million.[96] The large amount of capital required and the increasing cost of the coal needed to operate the plant are the two major reasons why all estimates for the prices of synthetic fuels are high, especially when compared to the low prices of almost all fuels only a few years ago.[97]

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compounds (and nitrogen from any air used)—plus organic "tars" and unreacted coal dust. Any unreacted coal, plus the ash, exists at the bottom of the gasifier as a char. The gases exiting at the top of the gasifier are cleaned of their tar and dust, and the hydrogen sulfide and other sulfur-containing compounds are removed to produce a clean gaseous fuel. If the raw gas is to be upgraded to a substitute natural gas, the hydrogen/carbon monoxide ratio is adjusted to the proper value (3:1) and then reacted over a catalyst (which speeds up the chemical reaction) to produce methane, the main constituent of natural gas.

Liquefaction of coal, as the name implies, results in the production of liquids from coal. The principle chemical problem is to increase the atomic ratio of hydrogen-to-carbon from its value of approximately 0.8 in solid coal to about 1.1 in the heavy liquid fuel produced. One way to carry out this "hydrogenation" of coal is by the reaction (in the presence of a catalyst) of hydrogen gas with the coal; that is, addition of hydrogen to the coal to form a liquid product, which can be separated from unreacted coal and ash. Hydrogenation of coal is carried out at high pressures and temperatures and is therefore a process which requires costly equipment. During hydrogenation over a catalyst, the sulfur originally present in the coal is converted to hydrogen sulfide gas, which is removed from the liquid product, thus producing a low-sulfur, low-ash, environmentally clean fuel.

95. *See, e.g.*, IGT-75, *supra* note 92.

96. Linden, *supra* note 27.

97. That the price of synthetic fuels will be high is a virtual certainty. The question is—what will be the relationship between the price of these fuels and other clean fuels such as natural gas and low-sulfur fuel oils. Also of crucial importance is the cost of imported oil, and very few people care to predict what this will be in the future.

Another crucial point with regard to the rate at which synthetic fuels from coal (or oil shale) will enter the United States supply is the environmental impact of these plants themselves. The synthetic fuels commercialization report stated:

> With regard to environmental impact, considerable uncertainty surrounds the commercialization of synthetic fuels. These uncertainties include choice of process, effluents from the processes chosen, pollutant transport mechanisms, site location, and others. Based on the environmental impact assessment it is judged that:
>
> - the environmental impacts currently estimated to result from the 350,000 bbl/d, or from the first phase of a two-phase 1,000,000 bbl/d option, appear acceptable when considered in light of the environmental and economic information likely to be gained from the program;
>
> - the environmental impacts likely to result from application of *current* conversion technologies and pollution abatement technologies on a large scale (1 million b/d [*sic*] or more) *would be regional in scope and could be severe*;
>
> - it appears that pollution abatement technologies can be developed which will render synthetic fuels and commercialization acceptable.[98]

Since this article is concerned with the near-term, that is from now until 1985, the present problem with the use of high-sulfur coal is the need to meet the environmental air pollution standards, in particular the limitations imposed on allowable SO_2 emissions from power plants and utility furnaces. Another approach that can be used to meet these emission standards for stationary sources is to remove or "scrub" the sulfur dioxide from the stack gases. A great deal of technical effort has been put into developing practical and economic processes to accomplish this. After years of development and testing, opinions are still mixed on the effectiveness of these techniques. A recent report issued by the Electric Power Research Institute states:

> The principal conclusion from this summary and analysis is that, although some progress has been made, long-term dem-

98. 1 SYNFUELS, *supra* note 35, at v (second emphasis added).

> onstration of reliable operation on a typical power-generating plant was not demonstrated in 1974. It is true that some specialized open-loop demonstration plants in the West did perform well in 1974 when burning very low sulfur coal. However, those specialized applications enjoy coal sulfur content and desert waste disposal conditions that are not typical for most of the U. S.
>
> . . . .
>
> Other unsolved problems are, control of process chemistry, waste sludge disposal, mist eliminator reliability, stack gas reheat, equipment erosion and corrosion, by-product marketing for recovery systems, and availability of limestone or lime for throwaway systems.
>
> . . . Unfortunately, it is not yet obvious that this technology is directly applicable to coal-fired utility boilers.
>
> There appears little doubt, however, that eventually scrubbers on coal-fired boilers, operating closed loop, will work with adequate reliability for the utility industry. It will then be a matter of (1) economics and (2) need for control.[99]

More recently, the Technical Advisory Board Panel on Sulfur Oxide Emission Control Technology of the United States Department of Commerce issued a report[100] that examined how soon, at what cost, and with what trade-offs commercially available continuous SO_2 emission controls can be installed, with arrangements for waste disposal, in coal-fired electricity generating plants of the Northeastern United States. This includes that part of the United States bounded by the Mississippi River and the northern borders of Tennessee and North Carolina. This region includes 19 states with 17 percent of the area of the contiguous 48 states, 50 percent of the United States population, and 65 percent of the total electricity generating capacity. The panel concluded that installation and operation of continuous SO_2 emission controls on all Northeastern coal-fired electricity generating plants cannot be met until the early 1980's, and then only with a maximum effort beginning immediately. Specific site and market constraints will determine the most economical and practical control technology for any given plant.

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99. ELECTRIC POWER RESEARCH INSTITUTE, STATUS OF STACK GAS TECHNOLOGY FOR SO_2 CONTROL vi, 2 (1975) (EPRI 209).

100. COMMERCE REPORT, *supra* note 10.

The panel found that several continuous SO_2 emission control technologies are commercially available.[101] Implementation of these technologies can be initiated now by most utility plants; however, the long leadtimes required for engineering design, obtaining disposal sites, permits, financing, manufacture and installation of hardware, and normal "debugging" will delay operation. Existing control technologies are: (1) the use of low-sulfur coals, (2) scrubbing of sulfur dioxide from power plant stack gases, (3) coal beneficiation, and, most importantly in their opinion, (4) the combined use of coal beneficiation to reduce, as much as possible, the sulfur content of the coal *plus* the installation of stack gas scrubbing to remove the major part of the sulfur emitted as sulfur dioxide.

IV. Conclusion

In summary, it should be apparent from this discussion of some of the aspects of coal mining and utilization that there are many technical problems concerned with the effective implementation of the legislative topics considered by this symposium. As we have shown, in addition to any legal limitations that may be imposed by these Acts, there also exist many technical restraints on our efforts to use coal to increase our domestic supplies of energy.

As should now be obvious, our country's energy situation is truly complex. The problem can be classified as "spherical"—no matter which approach is used to view the questions of energy supply and demand and the environment, the problem still appears the same. No easy solutions exist and efforts to frame the questions in a simplistic manner are not only futile, but probably counter-productive. Those who would state that the issue is a simple choice between a clean environment on the one hand and an increased energy supply on the other, evidence a failure to appreciate the complexity of the problem. That both a clean environment and an increased energy supply are desirable and also possible should be the starting point for any discussion and the end result to be sought.

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101. *Id.* at 3.