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ABSTRACT

This collection of data and graphics were prepared in response to a request from the White House Energy Policy and Planning Staff. The focus of this document is on those environmental issues which will, in the near and midterm future, prove important to the rapid development of domestic energy resources. This report emphasizes coal because of its prominence as an energy resource during this period. Other energy sources such as nuclear power, oil shale, oil, and gas are discussed to a lesser degree. Long term resources such as solar and geothermal resources are considered briefly, but references for further reading on these subjects are provided. The intent of the document is to communicate concepts rather than technical detail, thus data are approximate. (Author/RE)

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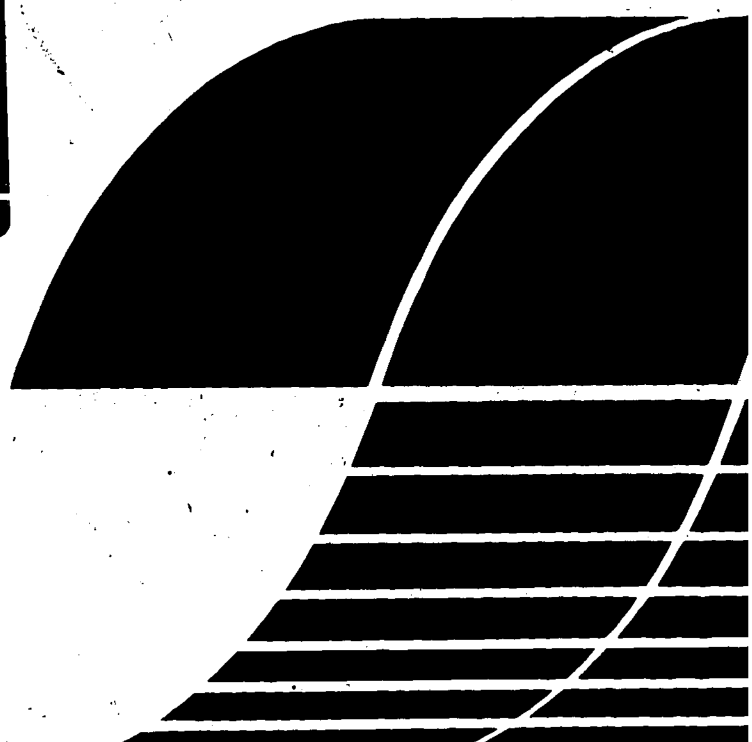

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The Energy/ Environment R & D Decision Series

This volume is part of the Energy/Environment R&D Decision Series. The series presents the key issues and findings of the Interagency Energy/Environment Research and Development Program in a format conducive to efficient information transfer.

The Interagency Program was inaugurated in fiscal year 1975. Planned and coordinated by the Environmental Protection Agency (EPA), research projects supported by the program range from the analysis of health and environmental effects of energy systems to the development of environmental control technologies.

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Acknowledgements

More than 50 individuals were involved in the gathering, synthesis and verification of the information in this fact book. Several deserve special mention. Jack Silvey of the Department of Energy's (DOE) Office of the Assistant Secretary for Policy and Evaluation directed the project and Sue Hickey and Gracie Hemphill reviewed and guided to fruition the various drafts. Bob Faoro, of the Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards, was of great help with the standards/status section.

In addition, many individuals from the EPA's Industrial Environmental Research Laboratories in Research Triangle Park, North Carolina, and Cincinnati, Ohio, contributed to this effort along with others from EPA's Office of Energy, Minerals and Industry. Finally, Joe Nash and George Shepherd of the DOE provided assistance in coordinating that organization's review of an earlier draft. To these, and to all the others who provided the data or did the research presented here, our sincere thanks.

Series Editor

The Energy / Environment Fact Book

Preface

The following collection of graphics and data were prepared in response to a request from the White House Energy Policy and Planning Staff. This information comprises the draft of Chapter 11 of the U. S. Department of Energy (DOE) Fact Book.

The focus of this chapter is on those environmental issues which, during the near and mid-term, will prove important to the rapid development of domestic energy resources. The most important energy resource during this period will be coal; the emphasis of this report is on coal. Other near and mid-term energy sources, such as nuclear, oil shale, oil and gas are discussed to a lesser degree. Some sources, such as solar and geothermal, are scarcely touched upon because of the long-term nature of their promise. However, good references for these can be found in the 'Further Reading' section at the end of the report.

Much of the information in this volume is approximate. It represents the latest data available in summary form. That data were drawn from differing sources using differing assumptions is obvious from the inconsistencies of some of the estimates. The intent here, however, is to communicate concepts rather than technical detail. In pursuit of this goal, many of the qualifiers which would otherwise accompany such scientific data have been eliminated. It is hoped that this editing process did no injustice to the truth. We welcome your suggestions.

United States Environmental Protection Agency
Office of Research and Development
Office of Energy, Minerals and Industry

January 1978

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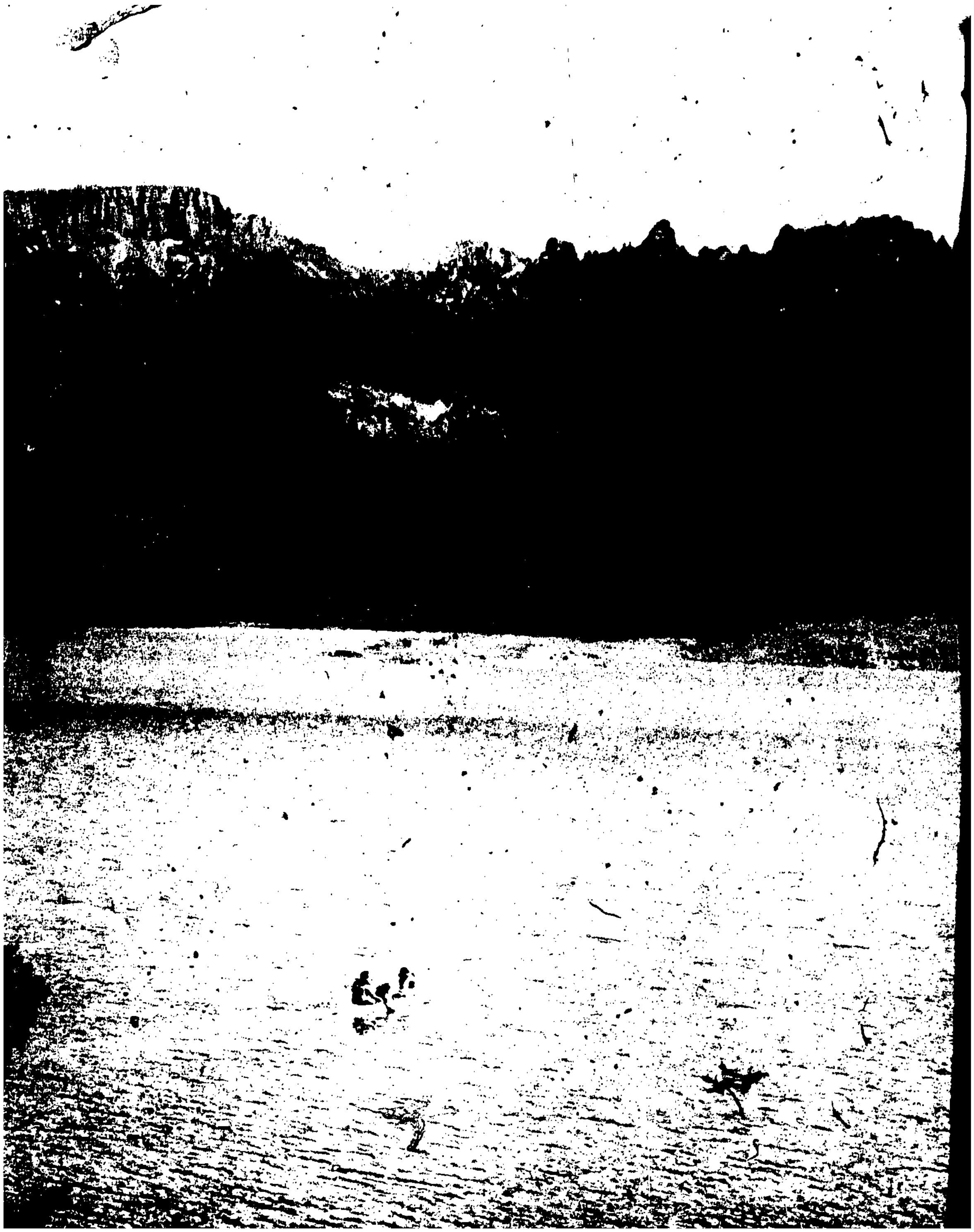

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Introduction

Energy systems, especially electric power generating plants, can impose upon the environment in many ways. Federal standards have been set for a number of the major pollutants from power plants. These standards are based upon the measured health and welfare impacts of such pollutants, and upon the availability of effective technologies to control the pollutants. They set maximum allowable levels of both air and water pollution. These levels limit either the pollution which a plant may emit (performance standards) or the concentrations of pollution to which people may be exposed (air quality standards).

Significant progress has been made in recent years in controlling several major pollutants. Others remain intractable. Emphasis in this section is upon those pollutants, such as sulfur oxides, nitrogen oxides and particles, which are most associated with coal combustion.

Contents

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and chart indicates gross quantities
tants released by stationary combustion
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in and natural sources. The right-hand
ates stationary sources of pollution into
es, and shows the relative proportion
water pollution and solid wastes from

Major Air Pollution Sources

Source	Particles		Sulfur oxides (SO_x)		Nitrogen oxides (NO_x)		Hydrocarbons (HC)		Carbon monoxide (CO)	
	10^6 ton/yr	% of total	10^6 ton/yr	% of total	10^6 ton/yr	% of total	10^6 ton/yr	% of total	10^6 ton/yr	% of total
Nature[a]	U[b]	U	4.2	11.9	U	U	30.7	45.5	U	U
Stationary Combustion	7.1	U	22.1	62.6	11.0	U	0.4	0.5	1.1	U
Transportation	0.8	U	1.1	3.1	11.2	U	19.8	29.3	111.5	U
Industrial Processes	14.4	U	7.5	21.3	0.2	U	5.5	8.1	12.0	U
Miscellaneous	12.8	U	0.4	1.1	2.4	U	11.2	16.6	26.1	U
Total	35.1	U	35.3	100.0	U	U	67.6	100.0	U	U

[a]Natural emissions estimated by multiplying total natural emissions by the ratio of U.S. to global land surface area.
[b]U = unknown

Sources: GCA Corp., 1976.

Emissions from Stationary Combustion Systems

	Air								Water			Solid waste		
	Particles, %	Sulfur oxides SO_x, %	Nitrogen oxides NO_x, %	Hydrocarbons HC, %	Carbon monoxide CO, %	Organics: BSO, %	Organics: PPOM, %	Organics: BaP, %	Total solids, %	Dissolved solids, %	Waste heat, %	Total ash, %	Fly ash, %	Desulfurization solids, %
Electric Generation	63.8	72.5	64.8	34.0	33.6	8.8	0.3	0.2	94	94	80	87	94	94
Industrial	28.3	14.5	24.7	22.3	14.9	20.0	0.5	1.3	6	6	20	10	6	6
Commercial/ Institutional	4.9	6.7	7.3	12.2	7.7	16.0	0.2	0.4	<1	<1	<1	1	<1	0
Residential	3.0	6.3	3.2	31.5	44.7	55.2	99.0	98.1	NIL	NIL	NIL	2	0	0
Total, 10^3 ton/yr	7,060	22,100	10,950	353	1,070	125	4.14	0.40	5,000	3,700	7.9×10^{15} BTU/yr	54,000	36,000	3,500

[a]BSO = Benzene soluble organics

PPOM = Particulate polycyclic organic material

BaP = Benzo (a) pyrene

Source: GCA Corp., 1976

Air Quality Standards

Limits for Exposure and Emissions

There are two types of federal standards set to control air pollution. *New Source Performance Standards* set a maximum limit on the concentrations and/or volume of emissions from each type of source (e.g., power plant). The other type, *National Ambient Air Quality Standards*, define the maximum tolerable concentrations for various pollutants in the air we breathe.

New Source Performance Standards apply to new or modified sources of emissions (e.g., power plants).

Ambient Air Quality Standards apply to the air we breathe. They are based upon measurements of the human health impacts of pollutants (primary standards) or of the welfare impacts of pollutants (secondary standards). These standards have been established by the Federal government for five pollutants: carbon monoxide, oxidants/ozone, particles, nitrogen dioxide, and sulfur dioxide. Fossil fuel combustion for power and transportation is responsible for most of the emissions of these pollutants. In 1975, national air monitoring indicated that standards for every pollutant were violated some place at some time.

The relationship between emissions and ambient air quality is complex and depends on wind and weather conditions, topography, stack heights, and temperature of emissions. For example, when the wind speed is low emissions may rise higher, spread more slowly, and reach the ground at a more distant point than with a high wind speed.

1975 Air Quality

		Stations at which Standards were Exceeded		Air Quality Control Regions (AQCR) which Showed Violations	
Pollutant	Standards	No.	%	No.	%
Total Suspended Particulates (TSP)	Primary annual	437 of 2186	20	116 of 216	53.7
Total Suspended Particulates (TSP)	Primary 24-hour	311 of 4137	7.5	108 of 243	44.4
Sulfur Dioxide (SO_2)	Primary annual	35 of 1357	2.6	12 of 187	6.4
Sulfur Dioxide (SO_2)	Primary 24-hour	132 of 2631	5.0	37 of 229	16.1
Carbon Monoxide (CO)	Primary 1-hour	28 of 436	6.4	15 of 117	12.8
Carbon Monoxide (CO)	Primary 8-hour	232 of 436	53.2	77 of 117	65.8
Oxidants/Ozone (Ox/O_3)	Primary 1-hour	356 of 416	85.6	96 of 102	94.1
Nitrogen Dioxide (NO_2)	Primary annual	19 of 824	2.3	5 of 128	3.9

Source: Faoro, 1977.

New Source Performance Standards for Fossil Fueled Steam Generators

	SO_2	NO_x[a]	Particles	Opacity[b]
Liquid Fossil Fuel	$1.4 g/10^6$ cal	$0.54 g/10^6$ cal	$0.18 g/10^6$ cal	20%
Solid Fossil Fuel	$2.2 g/10^6$ cal	$1.26 g/10^6$ cal	$0.18 g/10^6$ cal	20%
Gaseous Fossil Fuel	...	$0.36 g/10^6$ cal	$0.18 g/10^6$ cal	20%

[a]When fuel containing 25% by wt or more of coal refuse is burned in combination with other fuels, the NO_x standards do not apply.
[b]A maximum of 40% is permitted for not more than 2 minutes in any hour.

Source: 40 CFR 60.

Ambient Air Quality Standards

Pollutant	Time Period/Standard	Maximum Permissible Concentration
Total Suspended Particulates (TSP)	Annual, secondary	60 $\mu g/m^3$
	Annual, primary[a]	75 $\mu g/m^3$
	24-hour, secondary[b]	150 $\mu g/m^3$
	24-hour, primary	260 $\mu g/m^3$
Sulfur oxides (measured as SO_2)	Annual, primary	80 $\mu g/m^3$
	24-hour, primary	365 $\mu g/m^3$
	3-hour, secondary	1300 $\mu g/m^3$
Carbon monoxide (CO)	1-hour, primary	40 mg/m^3
	8-hour, primary	10 mg/m^3
Oxidants/ozone (O_x/O_3)	1-hour, primary	160 $\mu g/m^3$
Nitrogen dioxide (NO_2)	Annual, primary	100 $\mu g/m^3$
	Annual, secondary	100 $\mu g/m^3$
Hydrocarbons (HC)	3-hour, primary, secondary	160 $\mu g/m^3$

[a]Primary: to protect public health

[b]Secondary: to protect public welfare

[c]Hydrocarbons: Hydrocarbon standard does not have to be met if oxidant standard is met.

Source: 40 CFR 50

National Air Pollutant Emissions

These charts show emissions estimates by year and by the type of source. Particulate matter was significantly reduced (by 33%) and carbon monoxide moderately reduced (by 15%) over the six-year period 1970-1975. Transportation accounts for most of the carbon monoxide and hydrocarbons and nearly half of the nitrogen oxides emitted. Stationary fuel combustion and industrial processes are major sources of particulate matter, sulfur oxides, and nitrogen oxides.

Annual Estimates, 1970 - 1975

10^6 tons/yr

Year	Particles	SO_x	NO_x	HC	CO
1970	26.8	34.2	22.7	33.9	113.7
1971	24.9	32.3	23.4	33.3	113.7
1972	23.4	36.7	24.6	34.1	115.8
1973	21.9	35.6	25.7	34.0	111.5
1974	20.3	34.1	25.0	32.9	103.3
1975	18.0	32.9	24.2	30.9	96.2

Source U.S. EPA, 1976 b

National Emission Estimates By Source, 1975

(10^6 tons/yr)

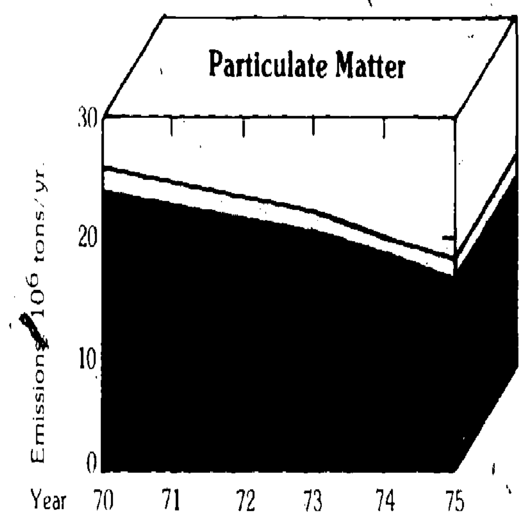
Source category	Particles	SO_x	NO_x	HC	CO
Transportation	1.3	0.8	10.7	11.7	77.4
Highway	0.9	0.4	8.2	10.0	67.8
Non-highway	0.4	0.4	2.5	1.7	9.6
Stationary fuel combustion	6.6	26.3	12.4	1.4	1.2
Electric utilities	3.5	21.0	6.8	0.1	0.3
Industrial fuel	2.5	5.0	4.9		
Other	0.6	0.3	0.7	1.3	0.9
Industrial processes	8.7	5.7	0.7	3.5	9.4
Chemicals	0.2	1.0	0.3	1.6	3.3
Petroleum refining	0.1	0.9	0.3	0.9	2.2
Metals	1.3	3.2	0	0.9	2.2
Mineral products	4.5	0.6	0.1	0	0
Other	2.6	< 0.1	< 0.1	0.8	1.1
Solid waste	0.6	< 0.1	0.2	0.9	3.3
Miscellaneous	0.8	0.1	0.2	13.4	4.9
Forest wildfires	0.4	0	0.1	0.6	3.3
Forest managed burning	0.1	0	< 0.1	0.2	0.5
Agricultural burning	0.1	0	< 0.1	0.1	0.6
Coal refuse burning	0.1	0.1	0.1	0.1	0.6
Structural fires	0.1	0	< 0.1	< 0.1	0.1
Organic solvents	0	0	0	8.3	0
Oil and gas production and marketing	0	0	0	4.2	0
Total	18.0	32.9	24.2	30.9	96.2

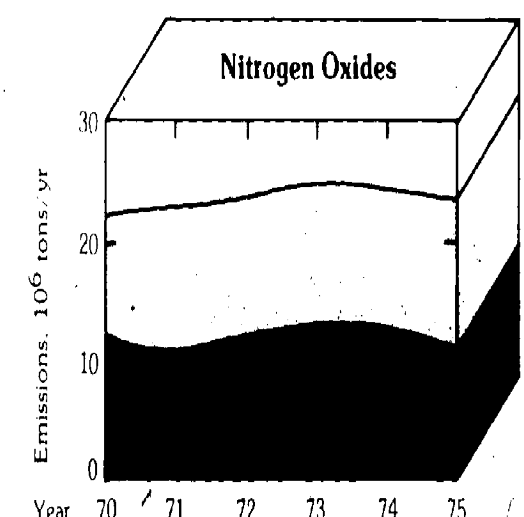
Source: U. S. EPA, 1976b.

Air Pollution Trends

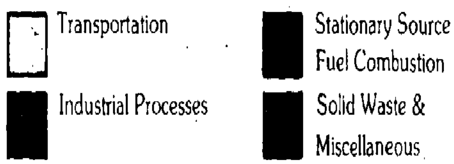
Progress Against CO and Particles

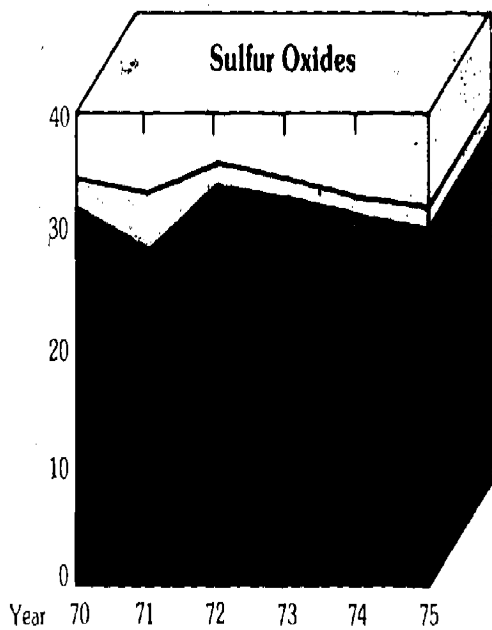
Improved automotive emission controls have resulted in lower carbon monoxide levels in the air. Control equipment, such as filters and precipitators in industrial and electric power plants, has reduced the concentration of particles in the atmosphere. However, comparable progress with other pollutants has not been achieved during the period 1970 to 1975.

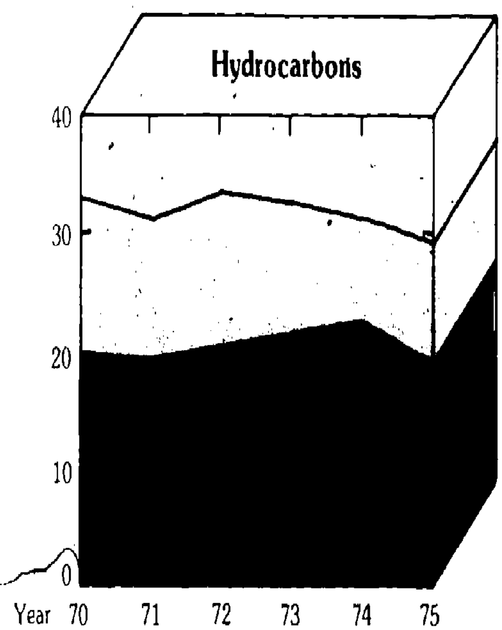


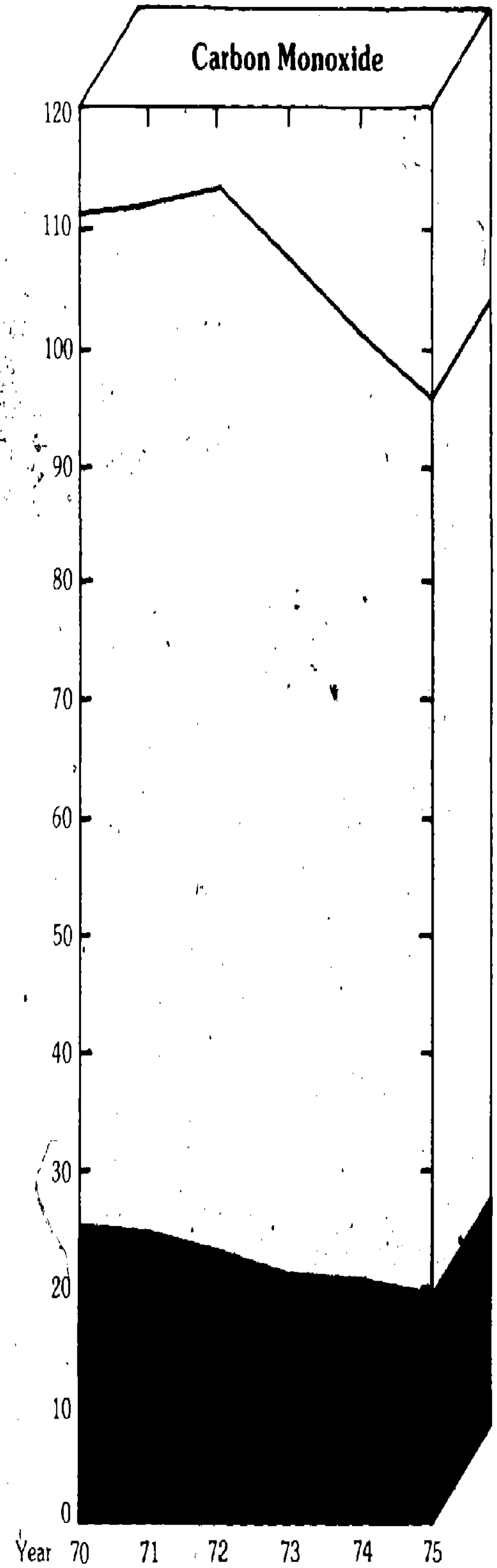


Air Pollution Trends: Emissions by Source









S. EPA, 1976b.

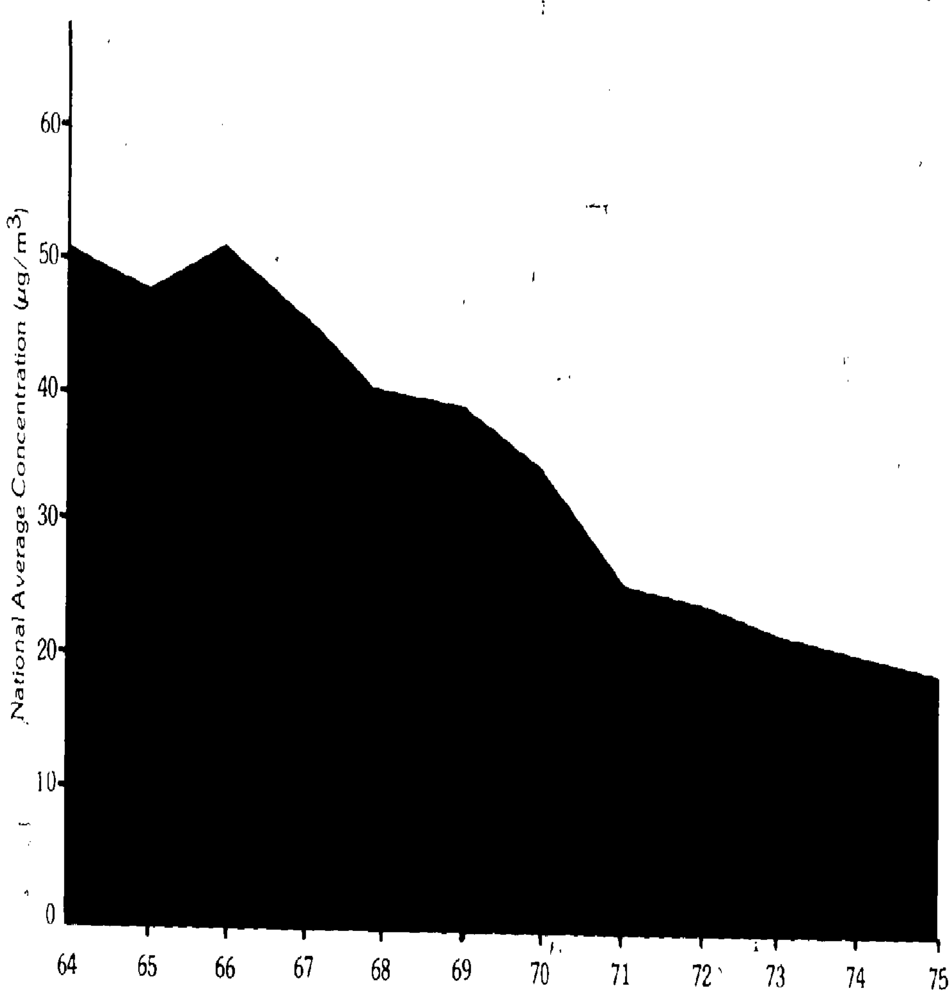
Sulfur Dioxide Trends:

Some Progress, Potential Problems

The major source of sulfur oxides in the atmosphere is the combustion of fossil fuels, especially those with high sulfur content. The most common sulfur oxide from combustion is sulfur dioxide (SO_2). Sulfur dioxide in the atmosphere converts to sulfates, which can damage the lungs, and to sulfurous or sulfuric acid, which increases the acidity of rainfall.

Over the past two decades, the shift to cleaner (low-sulfur) fuels such as oil and natural gas has resulted in a significant decline in the level of SO_2 in the atmosphere. This trend has leveled off recently. However, slight increases have been noted in places such as Los Angeles and parts of the Northeast. In Los Angeles, for example, relatively low sulfur dioxide levels have increased coincident with the curtailment of the use of natural gas as an industrial fuel. A shift to coal from natural gas and oil will require strict environmental controls if standards are to be maintained.

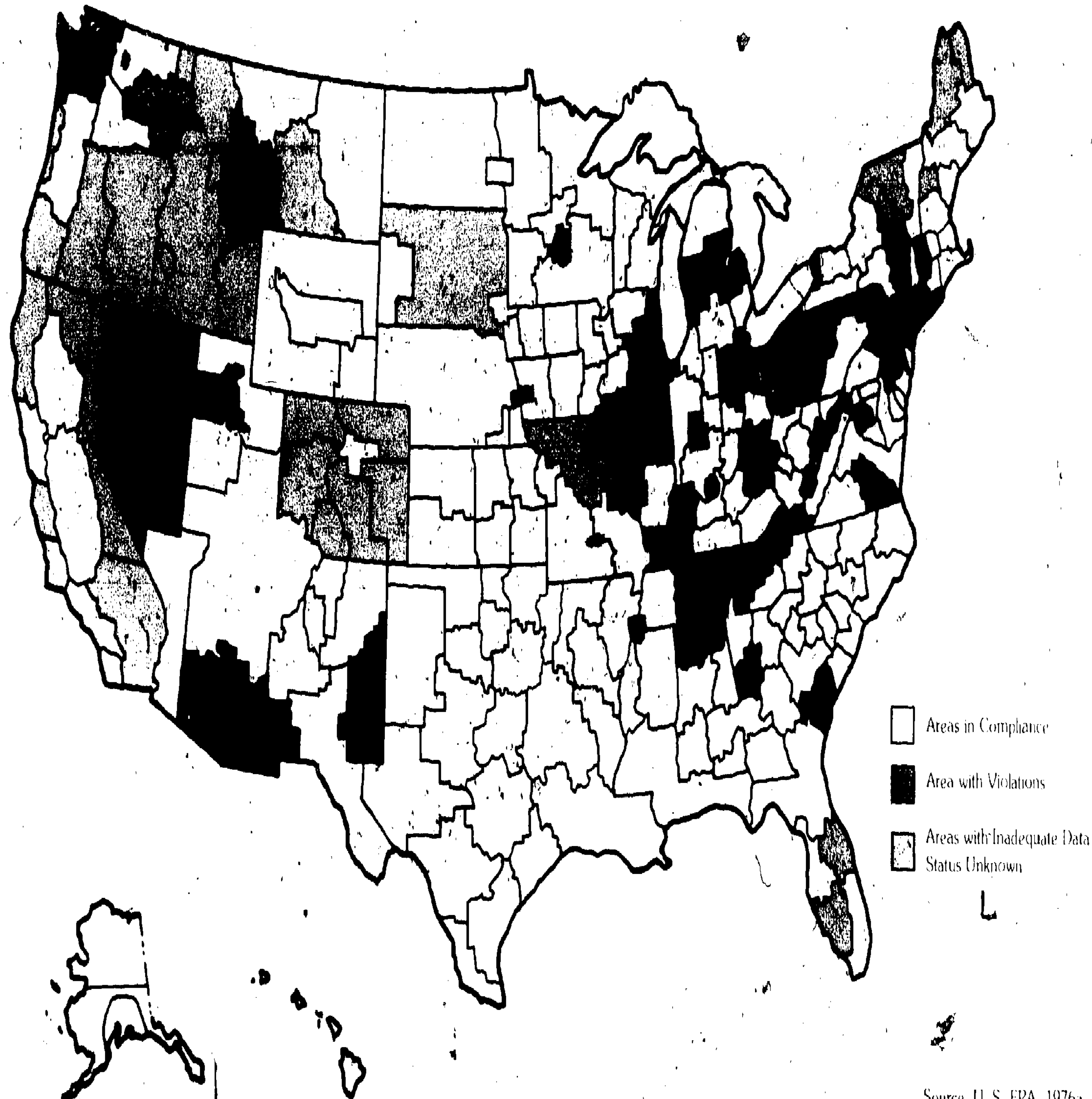
Trend in Average Annual Levels



Sources: 1964-1970 U.S. EPA, 1973, 1971-1975 U.S. EPA, 1976 b.

Air Quality Control Regions

Status of Compliance with Ambient Air Quality Standards for Sulfur Dioxide

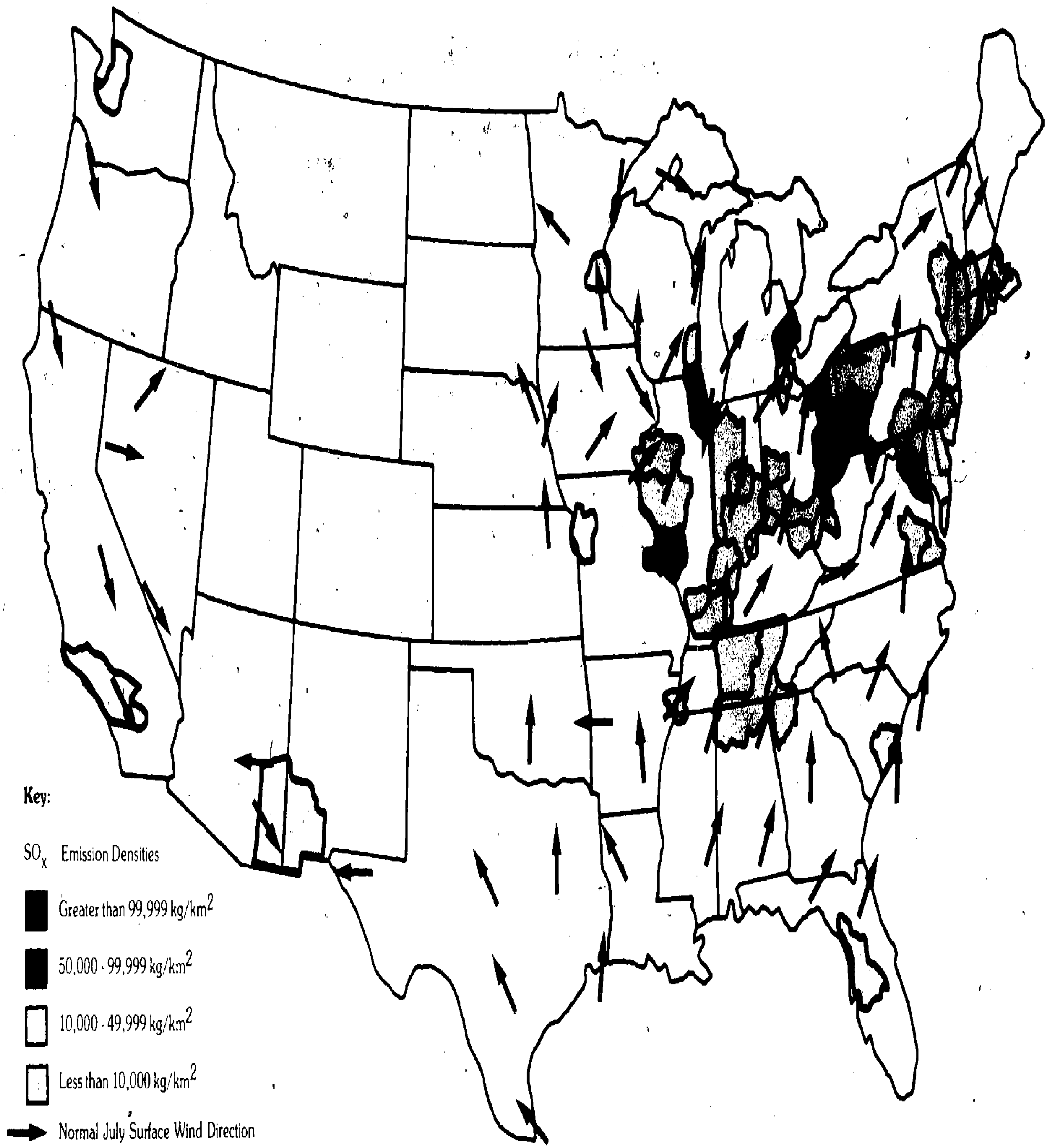


Source U. S. EPA, 1976a

Sulfur Oxide Emissions

Mainly from Stationary Sources

Large concentrations of sulfur oxide emissions occur in an area extending from Eastern Ohio, through Western Pennsylvania, to Maryland and West Virginia. This area accounts for more than 10 percent of the total sulfur oxide emissions in the nation. Another emission belt is located in Southern Illinois, Indiana, and Kentucky. Prevailing wind conditions tend to carry a portion of these sulfur oxide emissions, and their transformation products, into the populous urban areas of the Northeast.



Sources: Sulfur oxide emissions data from Teknekron, 1977.
Wind direction data from NAS, 1975.

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Total Suspended Particulate Matter Trends

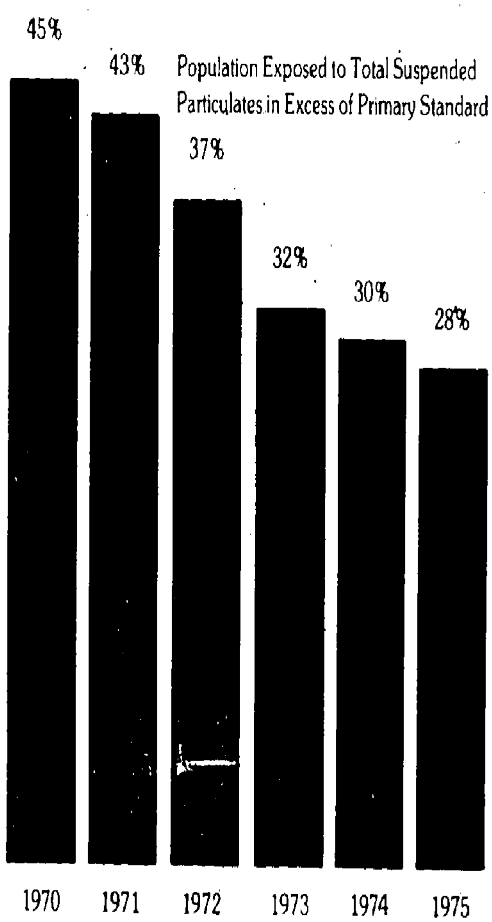
A Significant Improvement

Particles of dust, smoke, and mists suspended in the atmosphere are a widespread problem. Such particles, especially the fine particles, have been shown to imbed in lung tissues and can aggravate, or create, serious health problems.

Trends in particulate levels since 1970 show a general improvement at a rate of four percent per year, with the result that 38 percent fewer people throughout the country are exposed to levels higher than the health-based primary air quality standard. Improvement rates have differed in various parts of the country, with greater improvement in the Northeast and Great Lakes areas and lower rates in some Western States which have significant natural sources of particles.

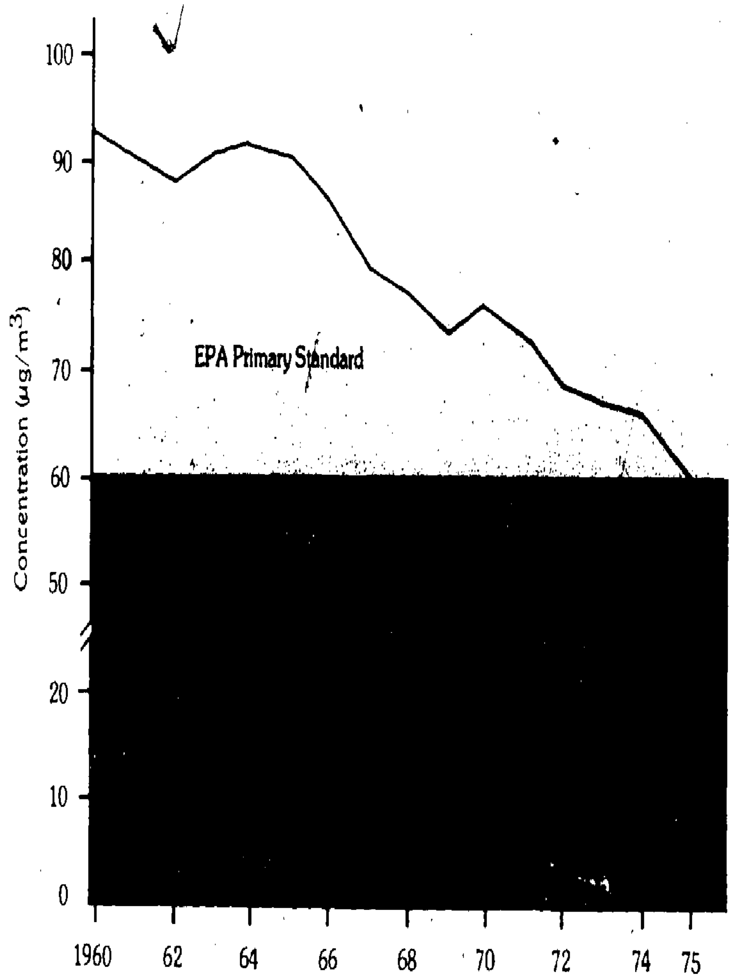
Despite the improvements, approximately 28 percent of the Nation's population still lives in areas where the annual standard is exceeded.

Trends



Source: U. S. EPA, 1977 a.

National Average



Sources: 1960-1970 U. S. EPA, 1973. 1971-1975 U. S. EPA, 1976 b.

Air Quality Control Regio

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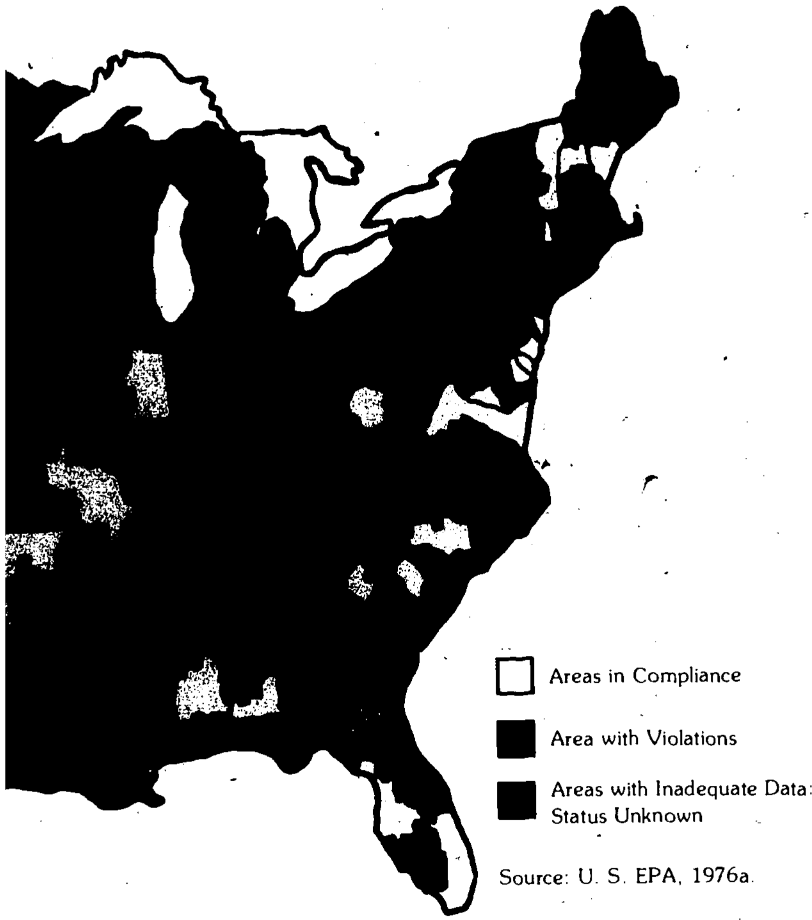

Source: U. S. EPA, 1976a.

State Air Quality Implementation P

Blueprints for Meeting Air Quality Standards.

Each state is required to show, through a comprehensive plan of development, transportation, and pollution controls, how it will meet national air quality standards. A review of these plans by the U. S. Environmental Protection Agency has determined that most of the plans were inadequate to meet standards for one or more pollutants. The maps show those states whose plans are inadequate to comply with standards for each of the five pollutants for which standards were set.

State Implementation Plans (SIPs), along with auto emissions and new source performance standards, are the primary modes of achieving National Air Quality Standards and pollution controls.

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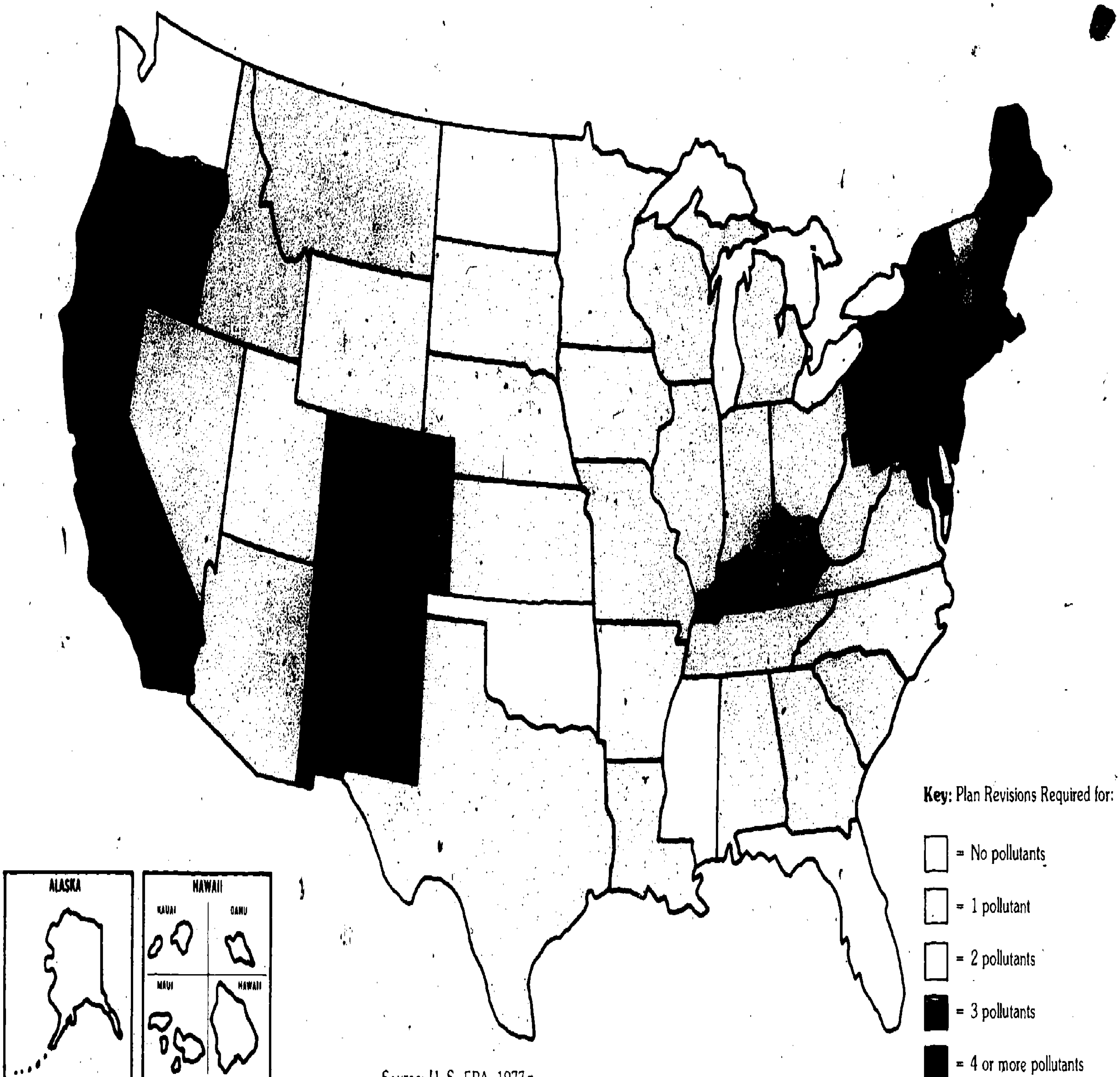
Summary: Number of Pollutants for Which Revisions Are Necessary.



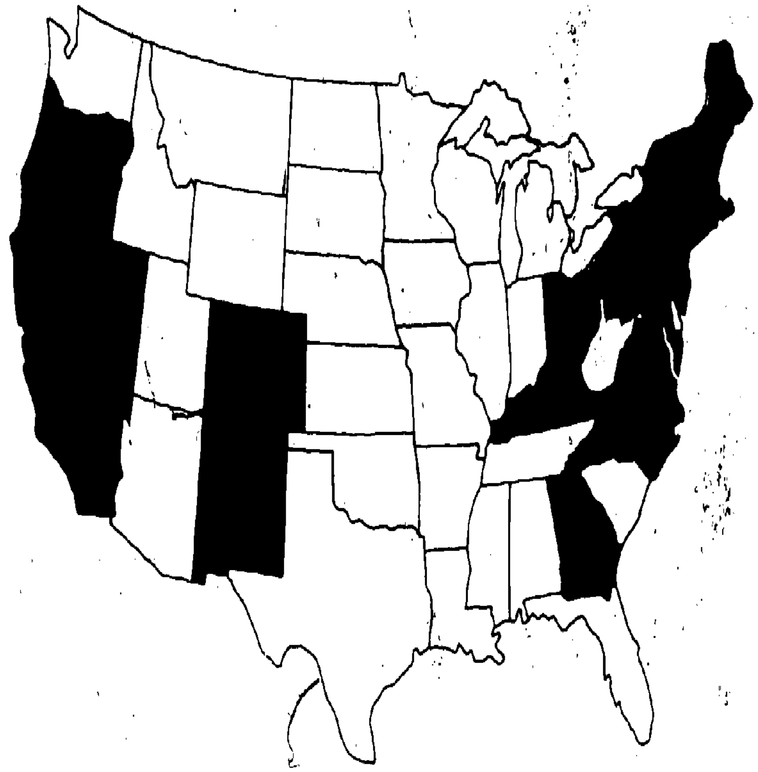
Source: U. S. EPA, 1977g.

States with Inadequate Air Quality Plans July 1, 1976

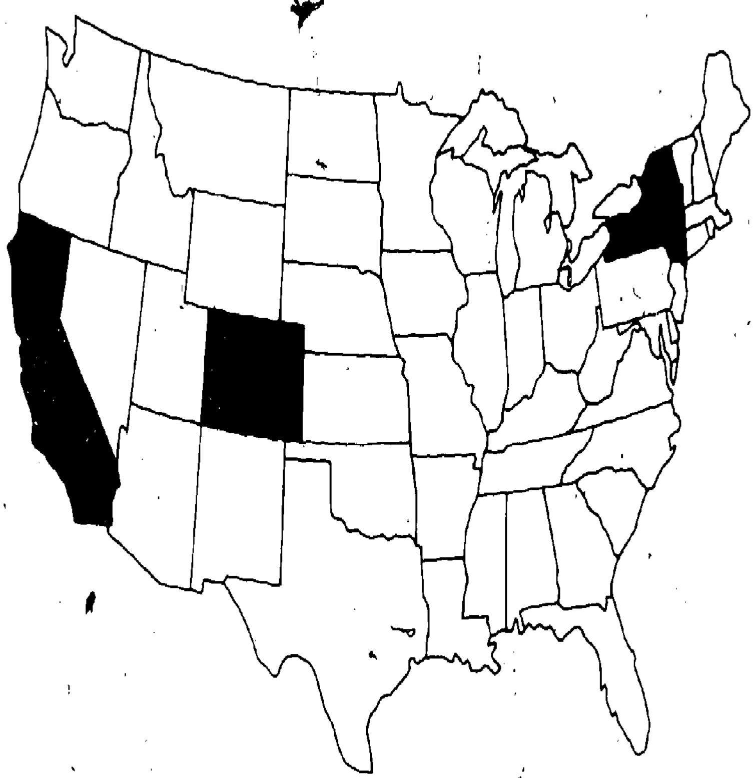
SIPs in the far West and in the East indicate widespread inadequacy to meet carbon monoxide standards. Nitrogen oxides are produced by stationary fuel combustion and, to a lesser extent, by transportation.

Combustion of fossil fuels in general, and of coal in particular, is a major source of sulfur oxides and particulates. Approximately 55% of human generated sulfur air emissions, and 25% of human generated particulate emissions, are from coal combustion for electricity.

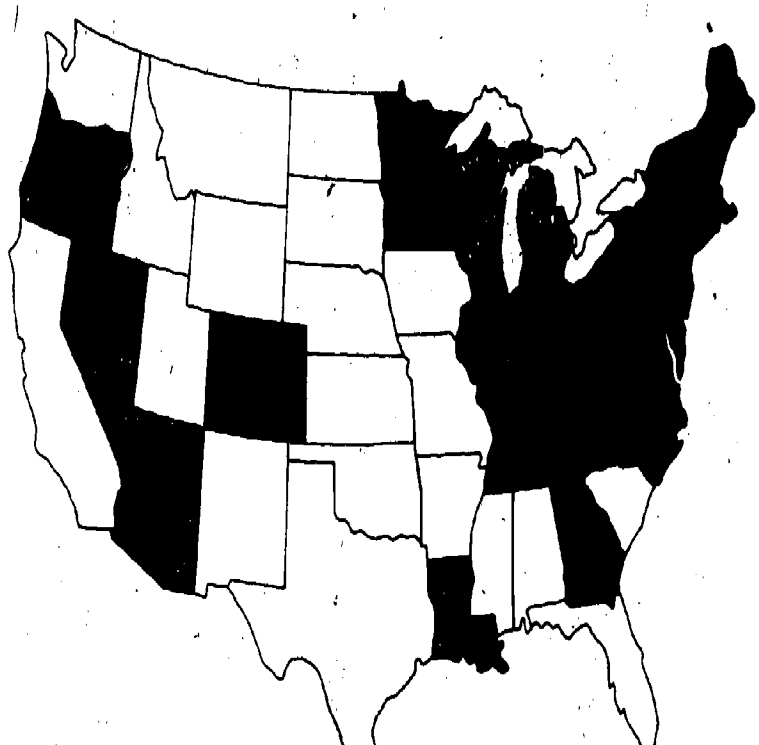
Carbon Monoxide



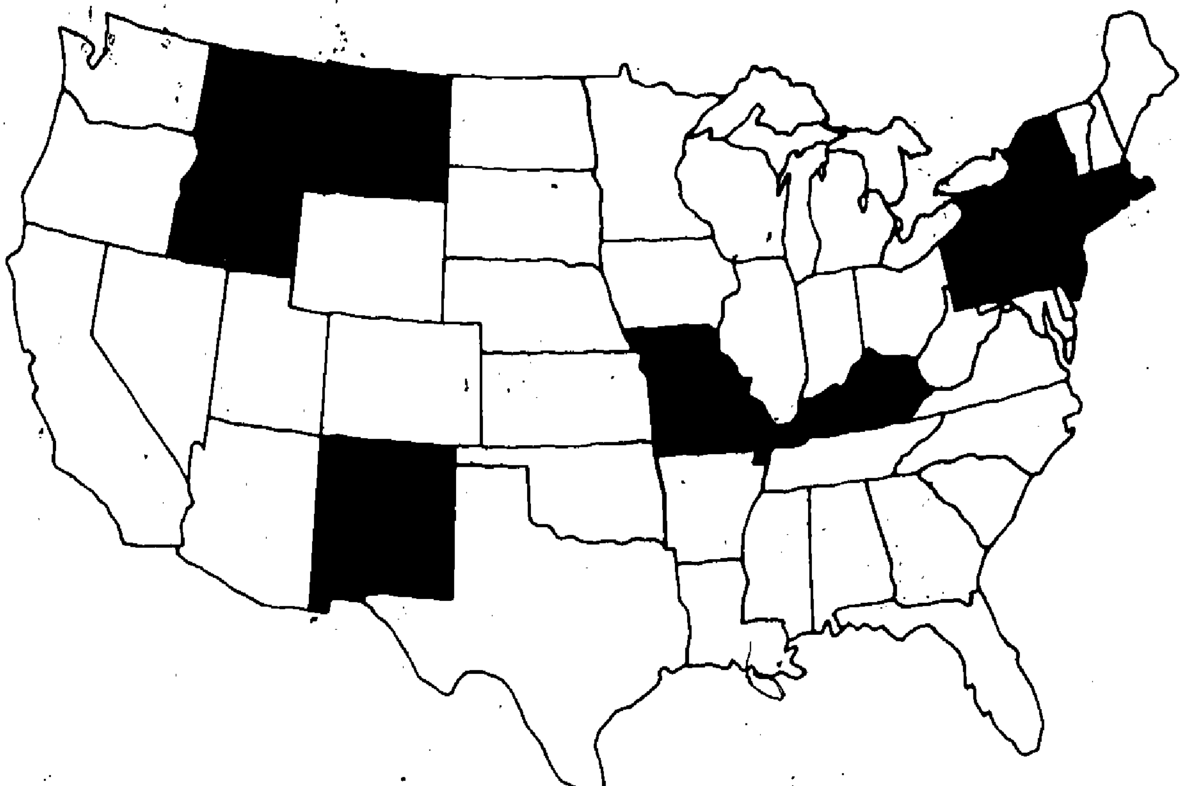
Nitrogen Oxides



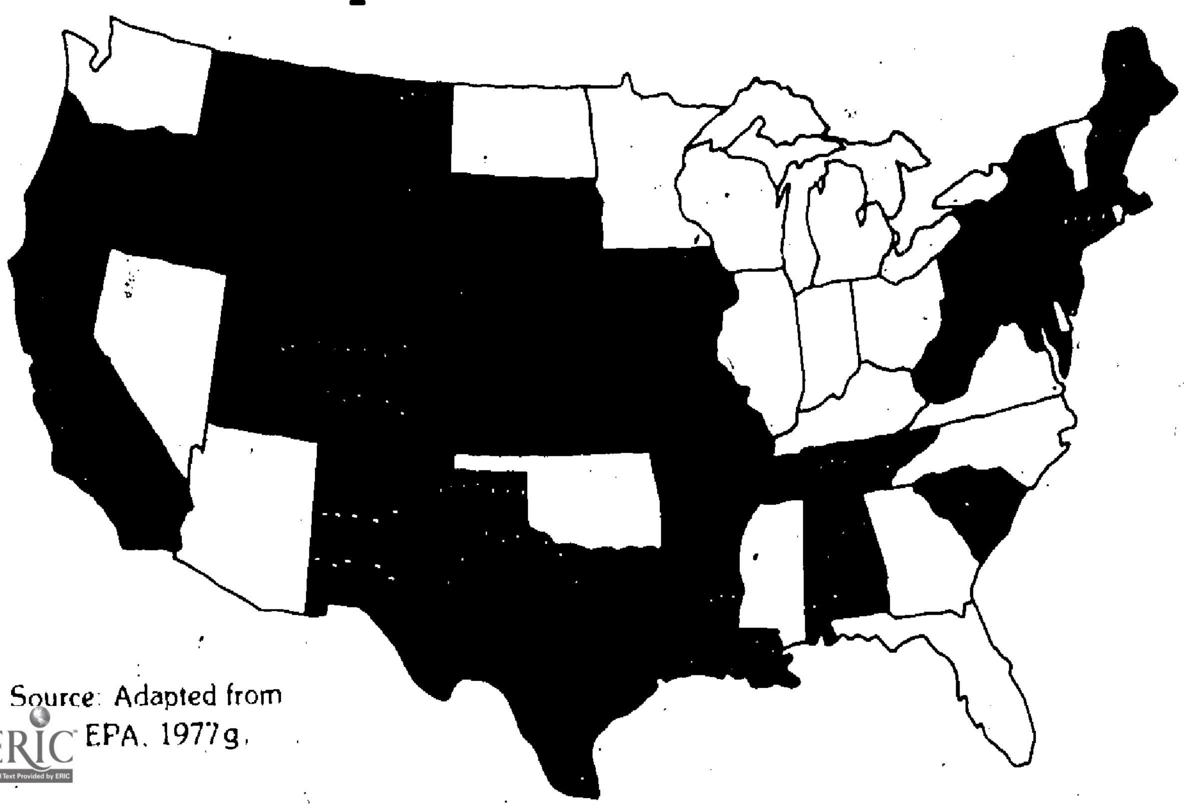
Oxidants



Sulfur Dioxide



Total Suspended Particulates



Source: Adapted from EPA, 1977g.

Water Pollution Standards

Controlling Water Impacts

Water pollution guidelines and standards are in effect for the specific pollutants that result from power plant operations. Allowable discharges for each pollutant are given in the accompanying table. In addition, polychlorinated biphenyls (PCBs), which are potential carcinogens, may not be emitted from any source.

Current federal regulations require that, with certain exceptions, closed-cycle cooling systems (i.e., recirculation cooling) be used on large steam-electric generating plants placed in service after 1970, and on certain smaller units placed in service after 1974. The cooling water discharge limitations for pollutants are shown in the opposite table under "cooling water blowdown".

Steam-Electric Power System Allowable Discharges

Pollutant Characteristic		Allowable Discharge is Effluent Flow Multiplied by the Following Concentrations in mg/l[a]										
		Total Suspended Solids		Oil and Grease		Copper, Total		Iron, Total		Free Available Chlorine[c]		Corrosion Inhibitor[d]
Effluent	pH	Max.[b]	Avg.[b]	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	
Low Volume Wastes	6.0-9.0	100	30	20	15	...	...	...	...	...	...	...
Bottom Ash Transport	6.0-9.0	100	30	20	15	...	...	...	...	...	...	...
Fly Ash Transport	6.0-9.0	100	30	20	15	...	...	...	...	...	...	...
Metal Cleaning Wastes	6.0-9.0	100	30	20	15	1.0	1.0	1.0	1.0	...	...	...
Boiler Blowdown	6.0-9.0	100	30	20	15	1.0	1.0	1.0	1.0	...	...	...
Cooling Tower Blowdown	6.0-9.0	...	...	...	...	...	...	...	...	0.5	0.2	NDA[b]
Area Runoff	6.0-9.0	Not to exceed 50		...	...	...	...	...	...	...	...	...

a. No discharge of polychlorinated biphenyl compounds such as those used for transformer fluid is allowed.

b. Abbreviations used: Max. = Daily maximum; Avg. = Daily average for thirty consecutive days; NDA = No detectable amount.

c. Chlorine may not be discharged on the average from any unit for more than two hours in any one day.

d. Includes zinc, chromium, and phosphorous.

Source: 40 CFR 423.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Alternative Fuels and Processes

Introduction

Different fuels, and different ways of using the same fuel, can produce dramatically different pollutant loads. In addition, these various fuels and processes each impose a range of demands on other resources, especially water. Choosing the right mix of fuels and processes requires a workable balance between energy needs, fuels, technologies, environmental constraints and other demands upon our limited resources.

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Alternative Fuels and Air Pollution

Coal Use Requires Stringent Emissions Control

The fuel used, the type of combustion technology, and emissions control technology all determine the amount of air pollutants emitted by electrical power plants. Power plants fueled with low-sulfur coal (e.g., 0.5%) can meet the emission requirements of current new source performance standards. But the use of the more abundant higher sulfur coal must also be expanded.

Flue gas desulfurization using high sulfur coal is one option. The advantages are lower sulfur emissions and expanded utility of high-sulfur eastern coals. The disadvantages are significant capital and operating costs, energy efficiency losses, and sludge disposal requirements.

Atmospheric fluidized bed combustion, still in the experimental stage, promises to give higher efficiencies and lower NO_X and SO_X emissions, but may also increase solid waste disposal problems.

Oil and natural gas are far cleaner to burn. These advantages are counterbalanced by the need for these scarce fuels for other uses such as home heating, transportation, and as chemical feedstocks.

Pollution from Different Fuels

1000 MW Power Plant 65% Load Factor with Various Controls

	Low Sulfur Coal[1,7] (0.5%S)	High Sulfur Coal[2] with FGD-85% (3.0%S)	Atmospheric[3] Fluidized Bed Combustion	Residual Oil[4] FGD-85 (3.0%S)	Natural[5] Gas	High BTU[6] Gasification
Fuel Consumption	**3,270,000 tons/yr**	**2,500,000 tons/yr**	**2,150,000 tons/yr**	**400×10^6 gallons/yr**	**56×10^9 ft³/yr**	**~60×10^9 ft³/yr**
Air Pollutants						
SO_X (ton/yr)	35,000	23,000	19,000	14,000	16	280
NO_X (tons/yr)	21,000	22,000	11,000	21,000	20,000	20,600
Particulates (tons/yr)	3,000	3,000	2,700	1,500	300	350
Other Pollutants						
Solid Waste (tons/yr) (Sludge)	0	700,000	1,200,000	450,000	0	60,400
Ash (tons/yr)	320,000	250,000	210,000	0	0	0

Source: U.S. ERDA, 1977 a.

[1] 33% Eff. 9,000 BTU/ton HHV
[2] 31% Eff. 12,500 BTU/ton HHV
[3] 36% Eff. 12,500 BTU/ton HHV
[4] 31% Eff. 150,000 BTU/gallon HHV
[5] 33% Eff. 1,050 BTU/sft³ HHV
[6] 33% Eff. 1,050 BTU/sft³ HHV (Conversion Emissions Added.)
[7] Medium-to-high sulfur coals can be physically or chemically cleaned. The use of cleaned coals is expected to produce pollutant loads similar to those of naturally-occurring low-sulfur coals.

Sulfur Emissions from Coal Combustion

Each Coal Is Unique

There is no such thing as a "typical" coal. Coals from different regions will vary widely in heat value per ton, moisture, ash and sulfur content. For example, many western coals are lower in sulfur content than eastern coals, but they are also lower in heating value. Hence, a greater quantity of western coal would have to be burned to produce the same amount of heat. As a result, the advantage of lower sulfur content in the western coals is at least partially offset by the requirement to burn more of these coals to obtain the same amount of heat. Such considerations make the choice of pollution control strategies for a particular site or application into an increasingly complex task.

SO_2 Emissions from Burning Different Coals[a]

	HEAT BASIS (LBS $SO_2/10^6$ BTU)		ELECTRICAL GENERATION 1000 MWe PLANT[d] (Tons SO_2/Year)	
% Sulfur in Coal	Western Coal at 9000 BTU/lb[b]	Eastern Coal at 13000 BTU[c]/lb	Western Coal at 9000 BTU[b]/lb	Eastern Coal at 13000 BTU[c]/lb
.2	.4	.3	14,000	10,000
.6	**1.3**	.9	**44,000**	30,000
1.0	**2.1**	**1.5**	**71,000**	**50,000**
3.0	**6.3**	**4.4**	**210,000**	**150,000**
5.0	**10.6**	**7.3**	**360,000**	**250,000**
7.0	**14.8**	**10.2**	**500,000**	**340,000**

Does not meet EPA standard: 1.2 lb $SO_2/10^6$ BTU.

Assumptions: [a] Based on 5% sulfur residue in ash.

[b] Typical of high-ash Western coals with percent Sulfur .2-3.0.

[c] Typical of high quality Eastern steam coals.

[d] No SO_2 controls; 75% operating time; 33% thermal efficiency; 67.3×10^{12} BTU/year thermal input.

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Emerging Energy Technologies

Impacts of Synthetic Fuels, Oil Shale

Alternative methods for converting coal to gas and liquid fuel, and for extracting oil from oil shale, may become significant energy sources within a decade. Each method, however, raises potential pollution impacts. Estimates of these impacts, and ways to control them, are currently under development.

Estimated Pollutants from Advanced Fuel Processes

	Units	Low BTU Gasification		High BTU Gasification		Coal Liquefaction		
		Western Coal	Illinois Coal	Western Coal	Illinois Coal	Western Coal	Illinois Coal	Oil Shale Colorado
Air[1]	tons/yr							
Particles		0.69	0.69	590	760	511	490	370
SO_2		470	1,815	1,450	8,390	1,200	1,580	4,290
NO_x		910	910	5,740	6,270	6,860	6,860	1,590
CO		26	26	300	330	270	270	140
HC		26	26	93	100	2,100	2,100	2,140
NH_3		46	37	28	45	—	—	—
Solid Wastes	tons/yr	360,000	490,000	374,000	530,000	372,000	570,000	$11,000 \times 10^6$
Land Use	acres	3,190	3,190	1,400	1,400	3,254	3,254	2,000
Water requirements	gal/yr	502×10^6	520×10^6	$4,300 \times 10^6$	$4,300 \times 10^6$	$2,200 \times 10^6$	$2,200 \times 10^6$	$1,400 \times 10^6$

[1]On the basis of an annual supply to a 1000 MWe power plant with .33 thermal efficiency and 75% load factor [67.3×10^{12} BTU/yr]

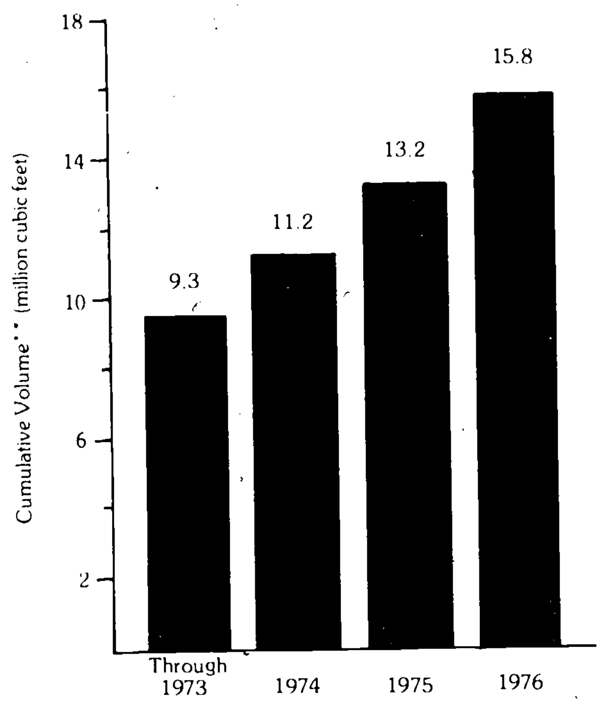
Source: Radian Corp., 1975

Nuclear Energy Questions

Just as with coal, nucle
environmental problem
environmental issues as
involve the entire nucle
and milling of ore throu

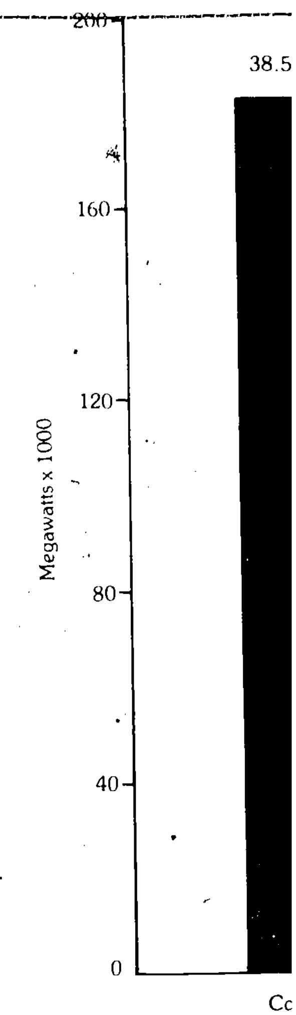
Quantities of Radioactive Wastes

Volume of Low Level Wastes* Buried in Commercial Disposal Sites



* Does not include recyclable fuel.
** About 50% of the volume is from power plants and 50% from other sources (e.g. medical uses)

Source: Dragonette, 1977.



Source: NERC, 1976.

# of Security and Wastes

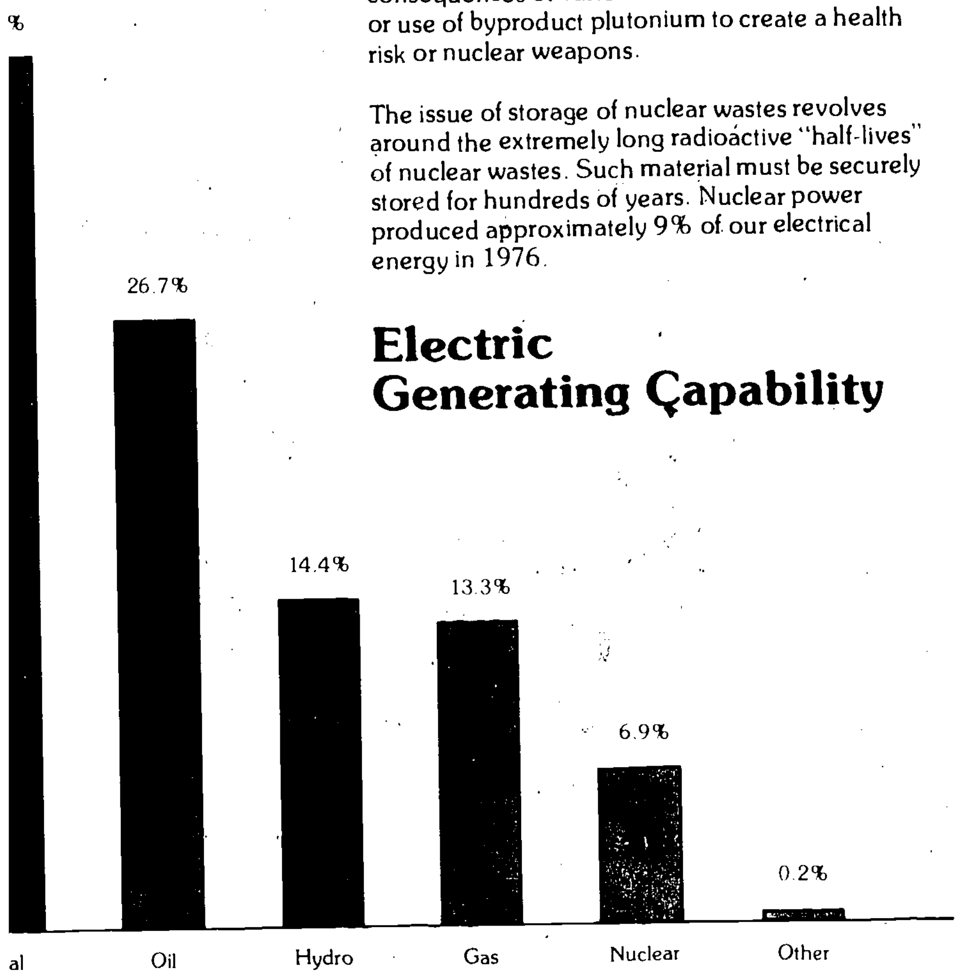
r fuel has its attendant
; and controls. The
sociated with nuclear power
ır fuel cycle from mining
gh enrichment, use,

recycling of spent fuel, transportation of fuels, and long-term storage of nuclear wastes.

Normal radiation emissions during the transportation, processing and power generation phases of the nuclear cycle are extremely low and have not been as much at issue as the potential consequences of various accidents, acts of sabotage or use of byproduct plutonium to create a health risk or nuclear weapons.

The issue of storage of nuclear wastes revolves around the extremely long radioactive "half-lives" of nuclear wastes. Such material must be securely stored for hundreds of years. Nuclear power produced approximately 9% of our electrical energy in 1976.

Electric Generating Capability

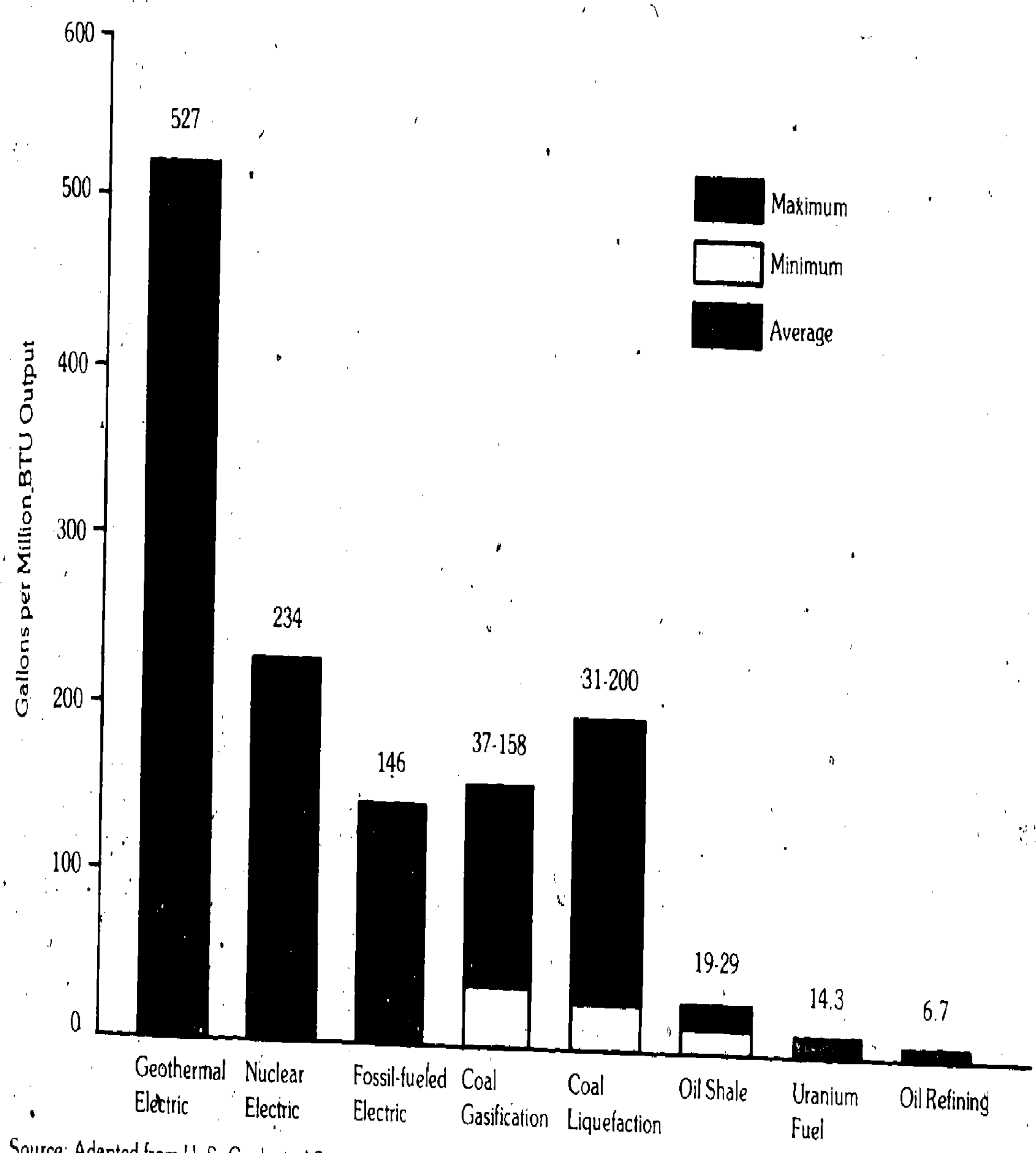


Water and Energy Development

Requirements of Different Fuels

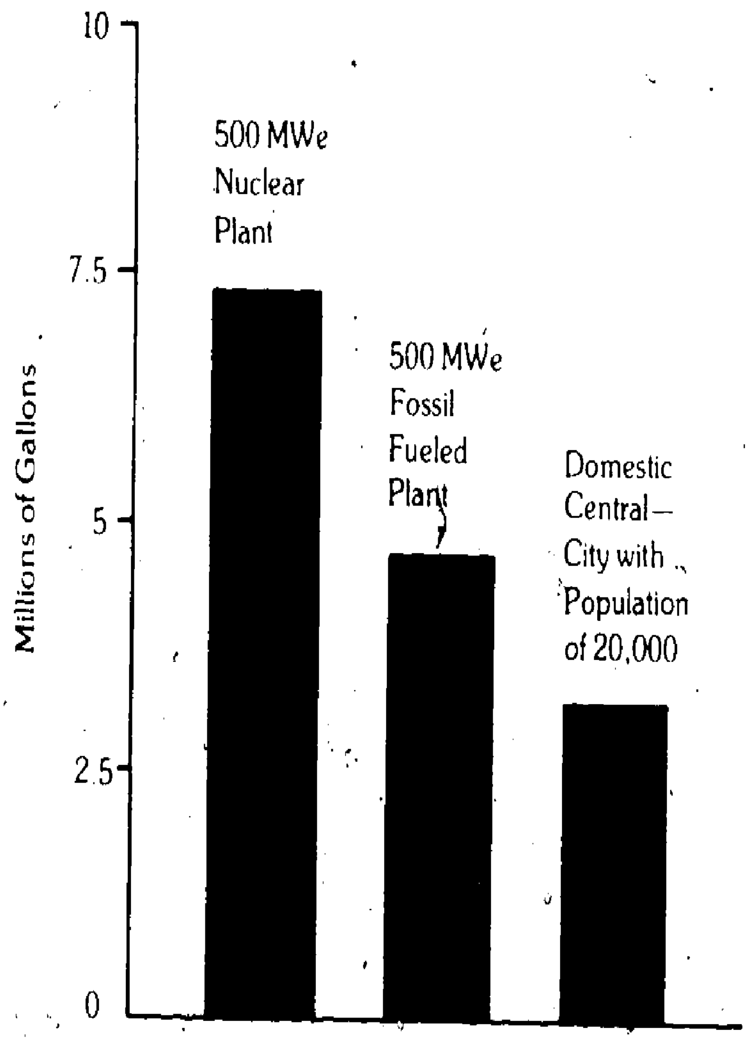
Nearly all sources of energy require water for refining and/or conversion and consumption. Therefore, availability of water in an area must be considered when choosing the locations for energy extraction, and the techniques used to extract and use that energy. In water-short areas, the need for water for energy extraction and processing must be balanced against other major water needs such as agriculture and municipal water supplies. For instance, the daily water use by a conventional 500-MWe electric generating plant is equal to that of a city of 30,000 population.

Water Consumption in Energy Systems



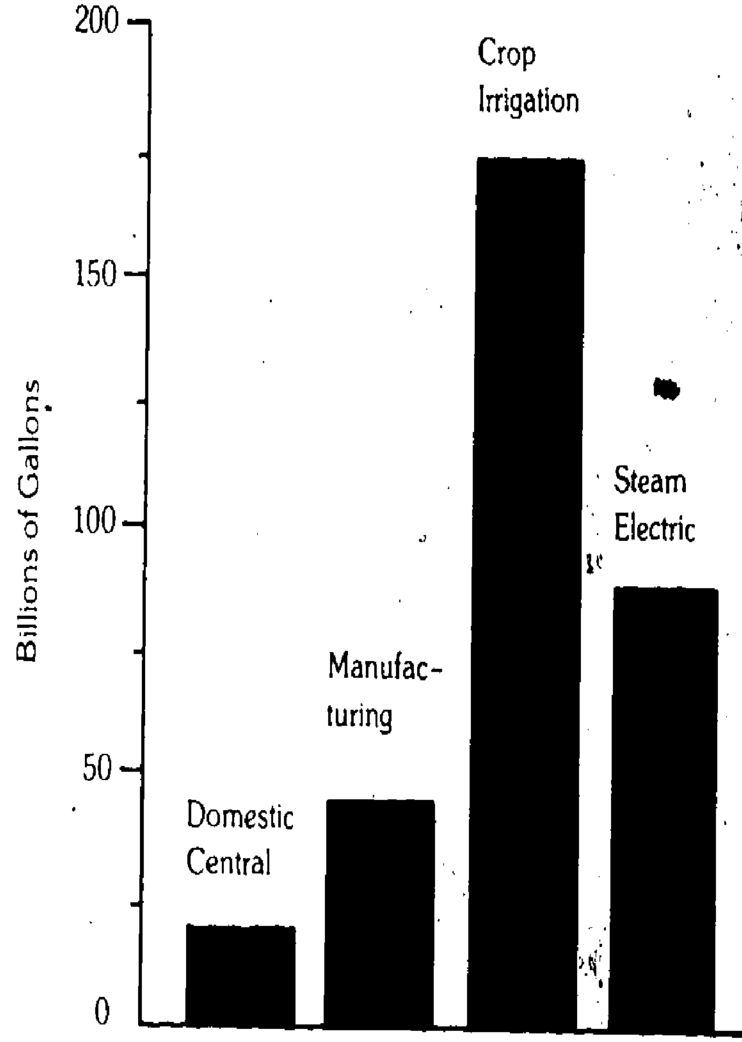
Source: Adapted from U. S. Geological Survey, 1974.

Daily Water Usage — Power Plants and Municipal Use



Source: Derived from data on other charts on this page.

Total Daily U.S. Consumption of Water for 1975



Source: Based on Hittman, 1976.

Energy Processes and Water

Estimates Will Vary

Precise estimates of water-use by various energy systems depend upon several major assumptions. As can be seen from the accompanying tables, different organizations at different times using different assumptions will produce different estimates. Such problems make energy-environment decision making an art as well as a science.

Water Requirements of Fossil Fuel Processes

Thermoelectric Generation

(Acre-feet per year)

	Unit*
U.S.G.S. Circular No. 703	(fossil) 13,450
	(nuclear) 21,500
Westwide Study	(fossil) 15,000
	(nuclear) 25,000
Water for Energy/Upper Colorado	(fossil) 17,650
Water for Energy/Upper Missouri	(fossil) 15,000
U.S. Dept of Interior Kaiporowits Draft EIS	(fossil) 16,500
U.S. Dept. of Interior (Hybrid)	(fossil) 4,400
San Juan Draft EIS (Wet)	14,400

*Unit: 1000 MWe/100% Load

Oil Shale Production

(Acre-feet per year)

	Unit*
U.S.G.S. Circular No. 703	(low) 12,150
	(high) 20,100
U.S. Dept. of Interior Draft EIS	(low) 7,100
	(mid) 17,000
	(high) 21,200
Western States Water Council	(low) 7,600
	(high) 18,900
Water for Energy/Upper Colorado	17,400
Brown, Kneese	17,922

*One unit = 100,000 bbl/day

Coal Gasification

(Acre-feet per year)

	Unit*
El Paso Gasification Plants (N. Mex.)	11,381
El Paso Gasification Plants (N. Dak.)	18,000
Wesco Gasification Plants	8,226
U.S.G.S. Circular No. 703	(low) 10,000
	(high) 45,000
Water for Energy/Upper Colorado	15,000
Water for Energy/Upper Missouri	10,000
NGPRP	9,500
Western States Water Council	10,22
Brown, Kneese	9,57

*One Unit = 250 x 10^6 scf/day

Source: Roach, Undated.

Pollution Controls

Introduction

This chapter focuses on the techniques, and their costs, for reducing air pollution from coal-burning systems. Some of the needed technologies are not yet available, especially for industrial-scale combustion systems. Such technologies, including coal gasification and fluidized-bed combustion, are currently being developed. Estimates are that, between 1976 and 1985, this country will spend more than $30 billion to control pollution from energy generating processes.

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Environmental Problems / Controls

Many Problems, Some Solutions

All phases of energy use—from extraction, to processing and conversion, to power generation, to final disposition of residual wastes—produce environmental impacts that could severely limit our ability to develop domestic energy resources. These environmental problems can, to a greater or lesser extent, be controlled. The table indicates some of the environmental problems associated with major phases of the development and utilization of coal, oil and uranium resources, and the relevant environmental controls to address these problems.

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Environmental Problems / Control Technologies

Extraction / Processing/Conversion

Coal

Extraction

Underground Mining
- Acid Drainage → *Contain/Neutralize*
- Solid Waste → *Well-Managed Landfill*

Surface Mining
- Runoff Solids, Acid Drainage, Sediments, Air Particles, Solid Waste → *Control/Treatment of Runoff*; *Well-Managed Mine Restoration and Revegetation*

Processing/Conversion

Physical Coal Cleaning
- Air Particles → *Dust Control*
- High-sulfur Solid Waste → *Recover Sulfur*
- Runoff Solids → *Contain*
- Acid Drainage → *Contain/Neutralize*

Gasification/Liquefaction (?)
- Runoff Solids → *Phys.-Chem. Treatment*
- Organic Wastes
  - Toxins, Carcinogens → *Phys.-Chem./Biochem. Treatment*
- Solid Waste → *Landfill*
- Waste Heat → *Cooling/Reuse*
- Fugitive/Accidental Release of Toxins, Carcinogens → *Design to Eliminate*

Petroleum

Extraction

Oil and Gas Wells
- Hydrocarbon Air Emissions → *Tighter Control of Fugitive Emissions*
- Liquid Wastes
  - Organics → *Biochem./Phys.-Chem. Treatment*
  - Saline Materials → *Reinject Brines*
  - Runoff Solids → *Phys.-Chem. Treatment*

Processing/Conversion

Refining
- Hydrocarbon Air Emissions → *Tighter Emission Control*
- Liquid Wastes
  - Organics → *Biochem. Treatment*
  - Runoff Solids → *Phys.-Chem. Treatment*
- Air Particles → *Tighter Emission Control*

Uranium

Extraction

Surface Mining
- Radioactive Tailings, Air Particles, Radioactive Runoff, Solid Waste, Sediments → *Contain All Radioactive Wastes*; *Contain/Treatment of Non-Radioactive Waste*

Processing/Conversion

Refining
- Fugitive Emissions of Radioactive Gases, Radioactive Solid Residues → *Contain All Radioactive Emissions*; *Long-term Storage of Radioactive Waste*; *Decommissioning of "Hot" Structures/Equipment*

Generation

Power Plants (Conventional)
- Sulfur Oxides → *Scrubbers, Fluidized-Bed, Clean/Cleaned Coal (?)*
- Nitrogen Oxides → *Scrubbers, Combustion Modification, Flue Gas Treatment*
- Flyash and Smoke Particles → *Cyclones, Baghouses, Electrostatic Precipitators, Scrubbers*
- Solid Waste (Ash) → *Well-Managed Landfill*

Industry
- Sulfur Oxides → *Fluidized-Bed, Clean/Cleaned Coal(?), Scrubbers*
- Nitrogen Oxides → *Combustion Modification*
- Flyash and Smoke Particles → *Electrostatic Precipitators, Baghouses, Cyclones, Scrubbers*
- Solid Waste (Ash) → *Landfill*

Commercial/Residential
- Sulfur Oxides → *Low-Sulfur Fuel*
- Nitrogen Oxides → *Combustion Modification*
- Flyash and Air Particles → *Electrostatic Precipitators*
- Solid Waste (Ash) → *Landfill*

? Technologies not yet available.
Source: Adapted from U. S. EPA, 1977 e.

Pollution Control Technologies

More Work to Be Done

Some energy-related pollution control technologies, especially for large utility boilers, are now available. Others, either more efficient, more economical, or more broadly applicable to other pollutants or uses (e.g., industry), require extensive research and development. Some of the key energy-related control technology issues are:

- **Development has concentrated on large units.** Control technology development for removing sulfur and, to some extent, nitrogen compounds from combustion gases has been concentrated on very large applications such as utility boilers.

- **Limited applicability.** The successful control technologies for large utility boilers are not always directly applicable for smaller size boilers or furnaces used by industry. The adaptation of control techniques for wide-scale application in industry may require 2 to 6 years or more beyond their availability for use by utilities.

- **Availability of low-sulfur coal.** Low-sulfur coal or physically cleaned (desulfurized) coal is usable in utility, industrial, or commercial applications, but is currently in short supply (about 10-20% of potential requirements). Development of major new mines and transportation facilities and/or construction of major new coal-cleaning facilities could increase the availability of low-sulfur coals. This would, however, require several years for completion and would involve significant capital investments.

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Applicability and Status of Pollution Control Technologies

Pollutants and Control Technology	Pollutant Reduction Efficiency (%)	Time Frame of Applicability		
		Utility	Industrial	Residential and Commercial
For SO_2				
Flue Gas Desulfurization	80-95	Current (New and existing plants)	Current for Large-Scale Installations Only—about 1980	Not Applicable
Physical Coal Cleaning	20-40	Current (Limited availability)	Current (very limited availability)	Current (very limited availability)
Chemical Coal Cleaning	10-60	Post-1980	Post-1980	Post-1980 (Limited applicability)
Use of Low-Sulfur Coal	12-30	Current (Limited availability)	Current (Limited availability)	Current (Limited availability/applicability)
Fluidized Bed Combustion (with chemical sorbent)	80-90	Post-1980 (Widely Applicable)	Current (Or very near-term)	Not Fully Evaluated
al Gasification				
Low BTU	90-95	Post-1980 (More applicable to new units)	Applicable Only to Largest Units	Not Applicable
High BTU	90-95	Post-1980 (New and existing units) (high costs)	Post-1980 (Widely applicable) (high costs)	Post-1980 (Widely applicable) (high costs)
Coal Liquefaction	90-95	Post-1985 (New and existing units)	Post-1985 (probably applicable to larger units only	Under Evaluation
Petroleum Desulfurization	High	Current (Fully applicable)	Current (Fully applicable)	Current (Fully applicable)
For NO_x				
Combustion Modification	20-80	Current (Applicable to certain types of units only)	Current—widely applicable for larger units	Partially Applicable (Under evaluation)
Flue Gas Denitrification	60-95	Post-1985	Post-1985	Not Applicable
Petroleum Denitrification	80-90	Current	Current—widely applicable for all size of units	Current—widely applicable
For Particulate Matter				
Inertial Devices (Cyclones)	98	Current (Widely applicable)	Current for Larger Installations	Not Required
Electrostatic Precipitators	>99	Current (Widely applicable)	Current for Larger Installations	Not Required
Wet Scrubbers	80-98	Current	Current	Not Required

Sources U.S. EPA, 1977i; Ponder, 1976a; Shimizu, 1975.

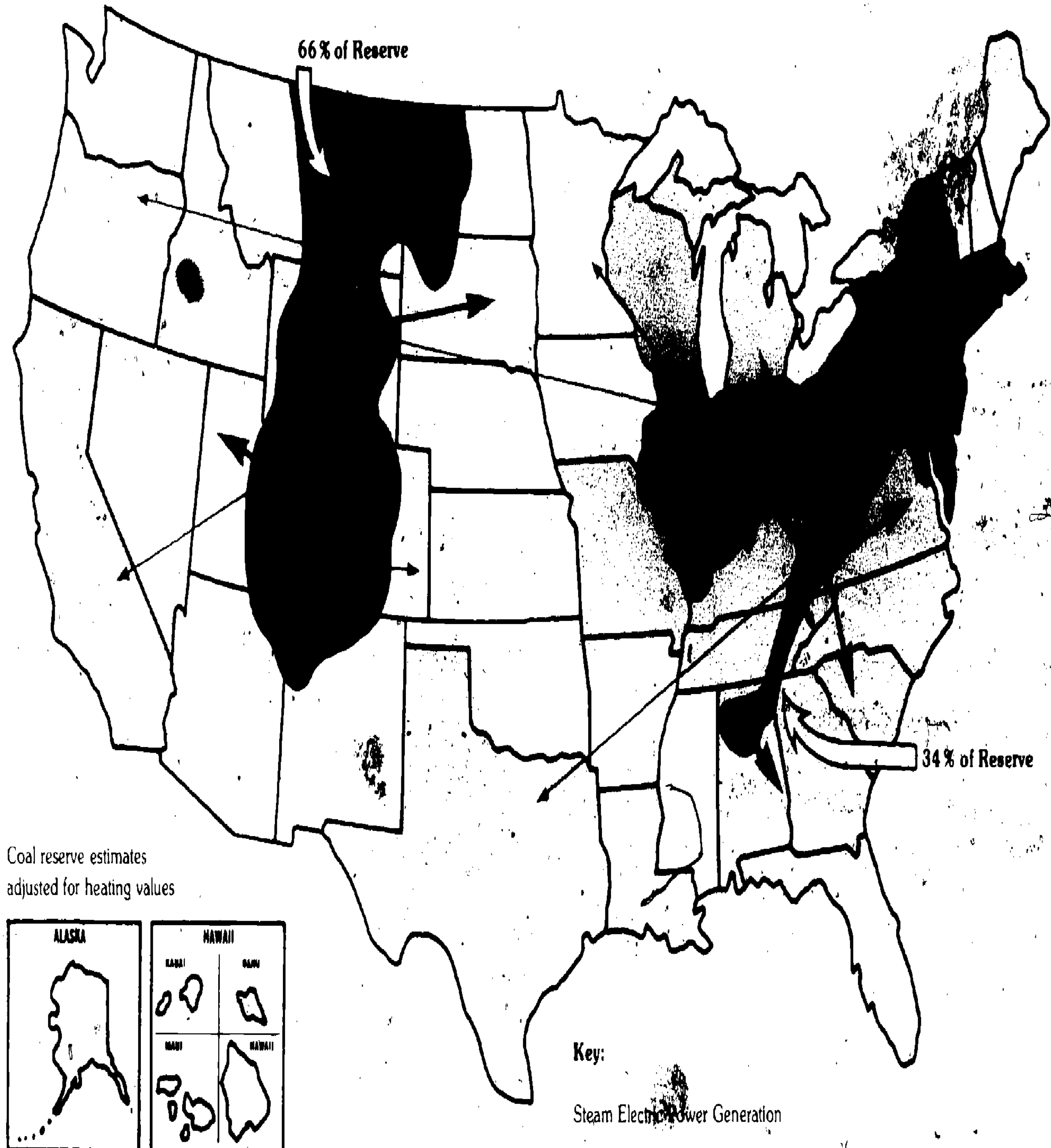
Low Sulfur Coal

A Naturally Cleaner Fuel

Use of low-sulfur coal is one approach to controlling the sulfur emissions from coal-fired power plants. Most of the low-sulfur coal reserves are in the west, while most of the steam-electric power generation (which will burn coal) is in the east and midwest.

Tougher environmental standards mean that a smaller portion of the low-sulfur coals will meet standards without additional controls. Many of the low-sulfur western coals are also low in heat content. This results in far higher transportation costs compared with eastern coals. Again, the coal consumer in the east and midwest must balance the economics of several alternative (or combined) methods of meeting air pollution standards. A major use of western coals may well be in the mine-site generation of power or production of synthetic fuels for transportation to user areas.

Low Sulfur Coal Reserves Vs. Steam Electric Power Generation



Coal reserve estimates adjusted for heating values

Key:

Steam Electric Power Generation

- > 1.5 Million KwH per Square Mile
- 0.5 - 1.5 Million KwH per Square Mile
- 0 - 0.5 Million KwH per Square Mile

Hawaii: Negligible Reserves and Consumption
Alaska: Potentially Large Reserves, Minimal Consumption

Source: Adapted from U. S. DOI, 1975

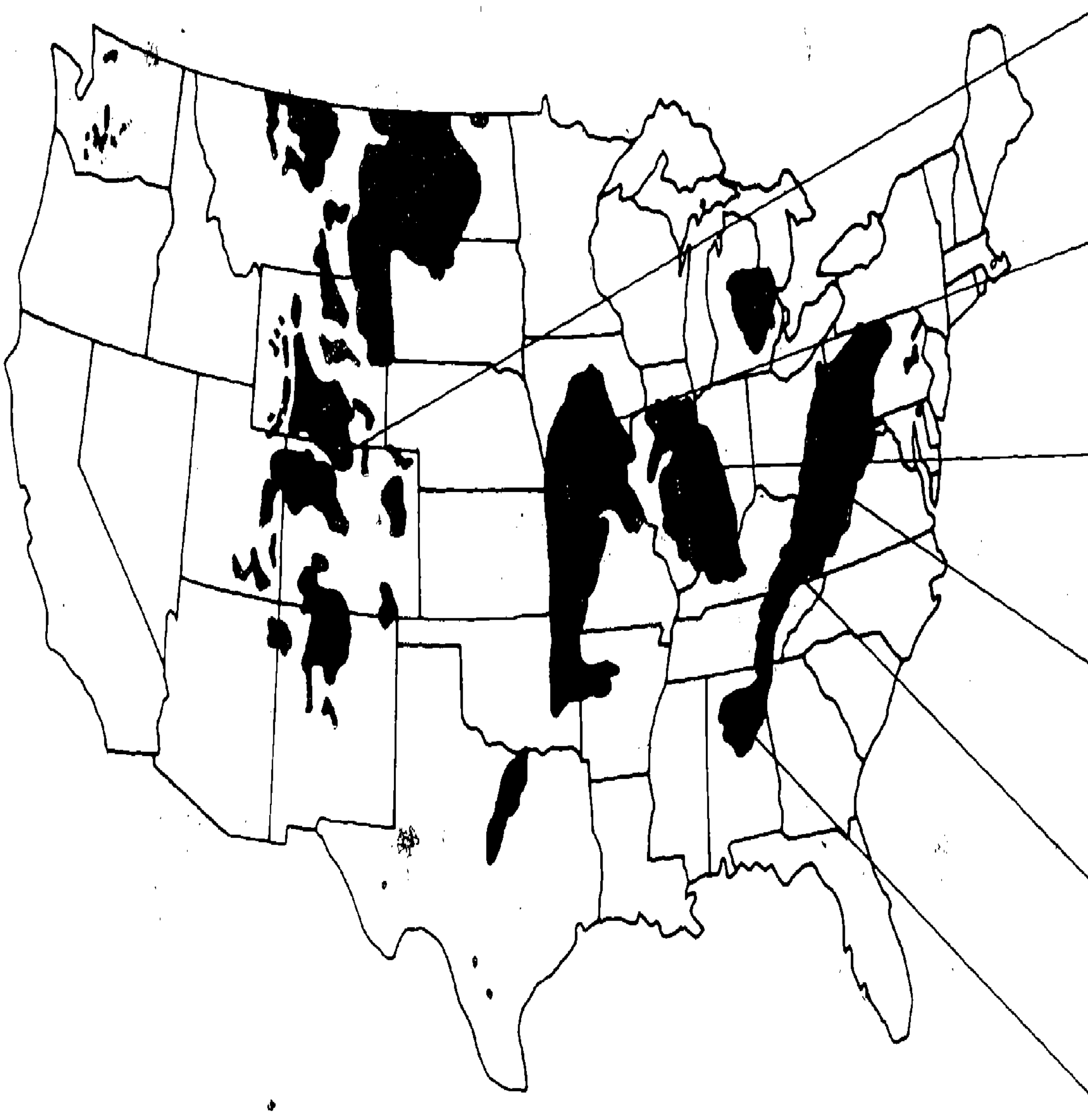
Coal Cleaning

A Partial Near-term Answer

Established methods of crushing and washing/separating (physically cleaning) coal can remove a significant amount of sulfur at the mine. The "cleanability" of a coal depends upon its composition, which varies markedly from one geographic location to another. Some coals can be cleaned sufficiently to meet current SO_2 emission standards. When more stringent standards are promulgated, other control methods will be required in addition to, or instead of, coal cleaning.

In interpreting the opposite chart, the reader should note that the quantities of reserve in various regions are given in terms of weight, not energy content. This latter measure varies greatly from one location to another. Also, one should note that the percentage cleanability estimates are based on a limited number of samples, and serve only as gross indicators of cleanability in the large regions shown.

Coal Deposits and Physical Cleaning



Western Region
Recoverable Coal Reserves (billion tons) . . 141
Meets EPA SO_2 Standards as Mined . . . . 70 %
Physically Cleanable to Meet
EPA SO_2 Standards (see note 3) . . 94-98 %

Western Midwest Region
Recoverable Coal Reserves (billion tons) . . . 11
Meets EPA SO_2 Standards as Mined . . . . . 3 %
Physically Cleanable to Meet
EPA SO_2 Standards . . . . < 6 %

Eastern Midwest Region
Recoverable Coal Reserves (billion tons) . . . 51
Meets EPA SO_2 Standards as Mined . . . . . 1 %
Physically Cleanable to Meet
EPA SO_2 Standards . . . . 2-4 %

Northern Appalachian Region
Recoverable Coal Reserves (billion tons) . . . 36
Meets EPA SO_2 Standards as Mined . . . . . 4 %
Physically Cleanable to Meet
EPA SO_2 Standards . . . . 12-31 %

Southern Appalachian Region
Recoverable Coal Reserves (billion tons) . . . 20
Meets EPA SO_2 Standards as Mined . . . . 35 %
Physically Cleanable to Meet
EPA SO_2 Standards . . . . 50-63 %

Alabama Region
Recoverable Coal Reserves (billion tons) 1
Meets EPA SO_2 Standards as Mined . . . . 30 %
Physically Cleanable to Meet
EPA SO_2 Standards . . . . < 40 %

Summary of U. S. Coals
Recoverable Coal Reserves (billion tons) . . 260
Meets EPA SO_2 Standards as Mined . . . . 14 %
Physically Cleanable to Meet
EPA SO_2 Standards . . . . 24-32 %

Potential New Standards
Figures on ability to meet EPA SO_2 standards refer to current new source emission standard of 1 2 lb SO_2 per million BTU A more stringent new standard is currently being considered by EPA If promulgated, the new standard would, in effect, reduce the percentages of "as mined" or "physically cleanable" coal capable of meeting the standard

Notes:

(1) Quantities of reserves in each region (given in tons) are not proportional to energy content For example, much of the vast reserves in the western region consists of types of coal with low heat content

(2) In this chart, 50% of deep coal is considered "recoverable reserve" in the "deep mined" category, and 85% of shallow coal is considered recoverable in the "surface mined" category

(3) Results reported above for ability to meet SO_x standards on an "as mined" basis or "physically cleanable" basis reflect percentages reported for 455 samples from all regions Because the cleanability and sulfur content of coal varies greatly within very localized areas, many more samples would be required to give precise estimates of the coal cleanability within each region. Percentage estimates given above refer to technical capabilities, and do not necessarily reflect economic conditions

Sources:
Hall, (undated) (Recoverable reserve data).
Cavallaro, 1976 (Cleanability data).

Scrubbers

Removing Sulfur After Combustion

The most promising sulfur-control technology to date has been a flue gas desulfurization (FGD) 'scrubbing' technique for which nearly $4 billion has been committed by industry. The combined electrical power output represented by this investment is 40,000 megawatts or 10% of this nation's generating capacity.

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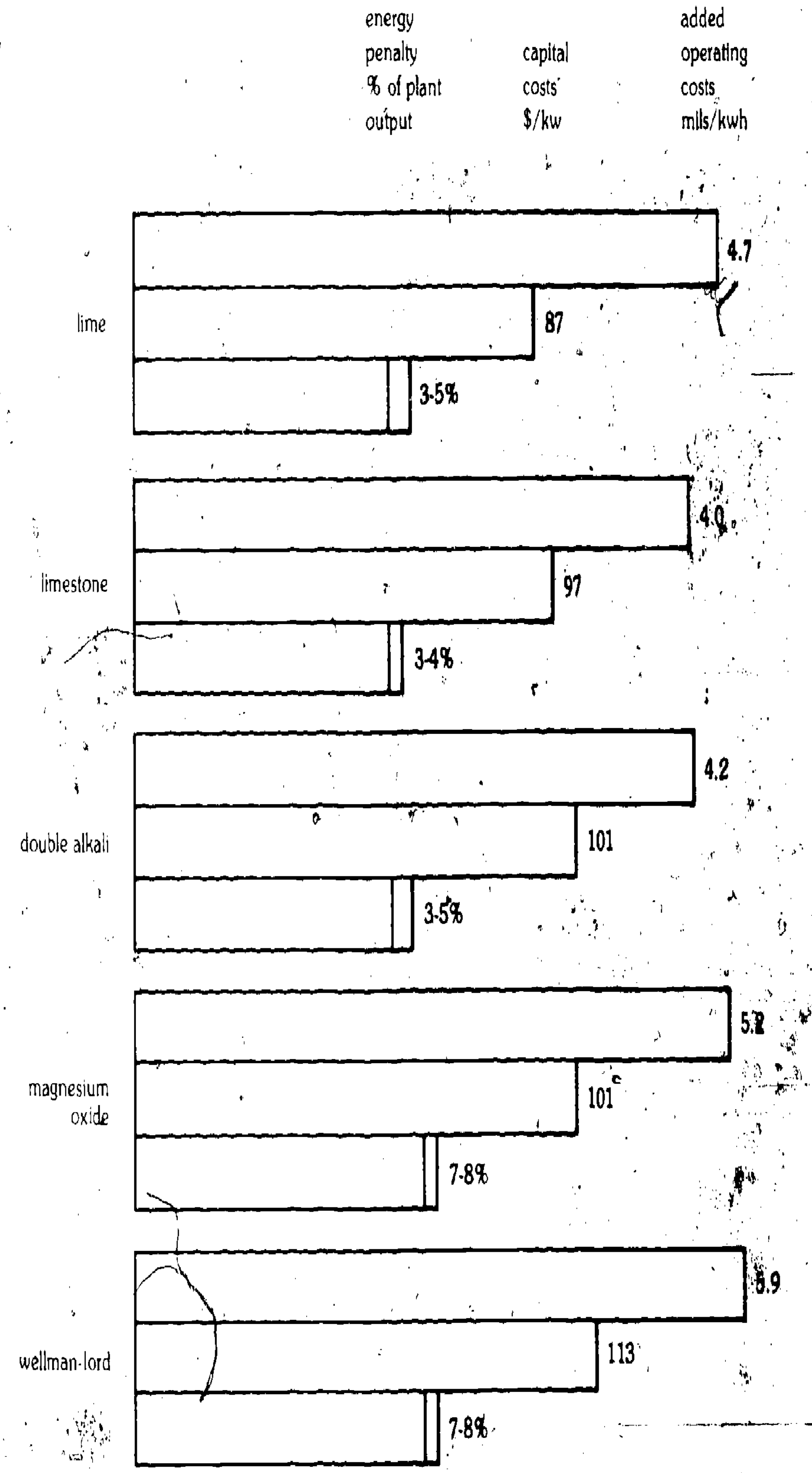
Costs Associated with Various FGD Systems for a 500 MW Plant



Source: U. S. EPA, 1977 h.

Costs of Alternative Pollution Controls

In Search of the Optimum Mix

There are a number of alternatives available for cleaning up sulfur dioxide, nitrogen oxides, and particulate matter resulting from fossil fuel burning. When incremental control costs alone are examined, there are wide ranges in capital, operating, and annualized costs for different technologies. Physical coal cleaning, for example, may be less than one-sixth as costly as flue gas cleaning, in terms of capital equipment, for removing a limited amount of sulfur. Unfortunately, coal cleaning is only partially effective in removing the sulfur and is not at all useful with some types of coal. Technology developments during the next five years in any one of these areas will significantly affect cost estimates.

Control Technology, Pollutant(s) Controlled, and Removal Efficiency (%)	Capital Equipment $/KW	Operating mills/kWh	Total Annualized mills/kWh	Pollution Control Costs as Percentages of Capital[3] Equipment Investment %
For SO_2 Control				
Flue Gas Desulfurization (~85%)	60-85[1]	2.1-3.6	3.4-5.4	13-19
Physical Coal Cleaning (20-40%)	9-22	0.15-1.20	1.5-2.0	2-4
Chemical Coal Cleaning (50%)		Technology in early stages of development		
Use of Low-Sulfur Coal (12-30%)	Depends on type of coal	Function of coal prices		0
Fulidized-Bed Combustion (>85%)		(Inherent in boiler cost)		
Coal Gasification (~95%)	75-125	N/A	N/A	17-28
Coal Liquefaction (~80%)	60-90	N/A	N/A	13-20
For NO_x Control				
Combustion Modification (20-60%)	0.50-7[2]	0.01-0.35	0.005-0.030	0.1-2
Flue Gas Denitrification (~75%)		(Expected to be equivalent to SO_x Flue Gas Desulfurization)		
For Particulate Matter Control				
Inertial Devices		(Used in conjunction with techniques listed below)		
Electrostatic Precipitators (>98%)	30-90	0.04-0.07	0.9-2.8	7-20
Fabric Filters (>99%)	38-48	0.01-3.0	1.5-2.5	8-10
Wet Scrubbers (80-98%)	49	~0.4	~2.0	11

[1] Costs based on installation in new units, 1977 dollars

[2] Costs based on 1975 dollars

[3] Running total plant costs of $450 million (1000 MWe)

Sources: Ponder, 1976a, Shimizu, 1975; Ponder, 1976b

The Bottom Line

Total Costs for Control of Energy-Related Pollution

Significant outlays will be required over the next decade for energy-related pollution controls. Even with such expenditures, however, it will be difficult to meet all health-based air quality standards in all areas.

Aggregated Expenditures (Millions of 1975 Dollars Except as Noted)

Industry Segment	Period Covered	Capital Investment	Total Annualized Capital Cost	Total Operating and Maintenance Cost
Air Pollution				
Coal Cleaning[1]	1976-85	14	30	14
Coal Gasification[1]	1976-85	120	68	53
Natural Gas Processing[1]	1976-85	51	180	242
Petroleum Refining[2]	1974-83	3,277	799 (in 1983)[4]	
Steam Electric Power Plant[3]	1975-85	20,000	N/A	2,700 (in 1985)
Water Pollution				
Petroleum Refining[2]	1974-83	2,666	1,064 (in 1983)[4]	
Steam Electric Power Plant[3]	1975-85	5,000	N/A	500 (in 1985)

[1]Source: U.S. EPA, 1977d.

[2]Source: U.S. EPA, 1976c (Amounts shown are in 1974 dollars and exclude $330 million capital investment for facilities to provide energy to operate EPA installations.)

[3]Source: U.S. EPA, 1976d.

[4]Combined total annualized capital costs and total operating and maintenance costs.

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Health and Environment

Introduction

The health and ecological effects of energy-related pollutants range from the subtle, long-term harm done by chronic exposure to sulfates to the tragedies caused by undergr[illegible] accidents. Perhaps the most pervasive e[illegible]ever, are the still-theoretical changes in g[illegible] climate which may be caused by the CO_2 from all fossil fuel combustion.

Contents

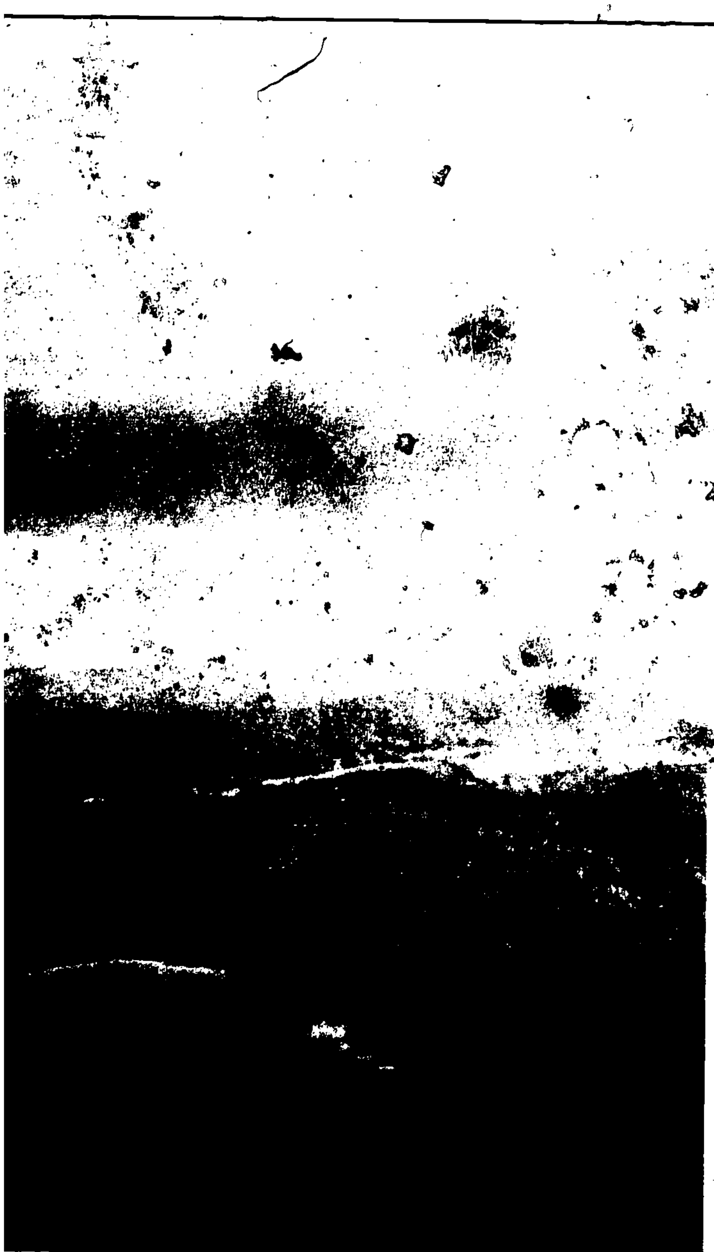
Health and Environmental Eff

Sulfur Oxides and Nitrogen Oxides

Energy-related pollutants must be controlled because of the damages they do to human health and the productive environment. EPA standards for air and water quality are based upon measurements of these damages.

Above certain exposure limits, energy-related air pollutants such as sulfur oxides and nitrogen oxides may aggravate emphysema and cause other forms of lung damage. These pollutants can also discolor and retard the growth of vegetation and crops.

Nitrogen oxides and their reaction products can be absorbed or precipitated out of the air and into water supplies. As either an air or water pollutant, nitrogen compounds can cause serious illness and dramatic changes in vegetation.



Effects of Energy Pollutants—SO_x and NO_x

Pollutant	Health Effects	Effects on Vegetation	Effects on Aquatic and Terrestrial Organisms	Air Standards	Water Standards
Sulfur Oxides SO_X	$SO_2 \rightarrow SO_3 \rightarrow H_2SO_4$. The heart and lungs are the major target organs for SO_X. The presence of SO_X increases bronchio constriction hence aggravating asthma and emphysema and decreasing lung ventilation.	Sulfur oxides are highly toxic to vegetation; effects include: interveinal necroses, yellowing of broadleaf species and reddish discoloration of conifer needles. Acid rains may also damage vegetation or alter soil conditions.	Aquatic communities m[illegible]be affected by increasing acid conditions due to acid rains. Animals are sensitive to high SO_X concentrations.	TLV* for SO_2 is 5.0 ppm. Federal Primary Ambient Air Standards for SO_2 are: 365 $\mu g/m^3$ (0.14 ppm) - 24 hr. standard; 80 $\mu g\ m^3$ (0.03 ppm) annual standard. The secondary standard is 1300 $\mu g/m^3$ (0.5 ppm).	
Nitrogen Oxides NO_X	$NO \rightarrow NO_2$ by photochemical oxidation. NO_2 is four times as toxic as NO. At high levels NO_2 causes pulmonary edema and death while at low levels the effects include emphysema, polycythemia, leucocyto[illegible]s and sensitivity to infection. In addition to lung damage, liver kidney and heart damage may occur. Eye and s[illegible]n irritation may [illegible] occur. NO_X exposure correlates with lung cancer induct[illegible]. NO_3 and NO_2 in w[illegible]er may cause methemoglobinemia and death. NO_2 may cause cancer.	Adverse effects on plants from NO_2 include: defoliation, chlorosis, irregular necrotic spots, tip and margin burn, high leaf gloss, inhibition of photosynthesis and growth retardation. Middle age, rapidly growing leaves are most sensitive. Nitra[illegible] because it is an im[illegible]ant [illegible] nutrient, is considered [illegible] set in irrigation water.	Nitrates in water are rapidly removed by aquatic plants and may result in eutrophication. Nitrogen (nitrate or ammonia) should not exceed 0.3 mg/l in lakes or 1.0 mg/l in free-flowing streams to prevent algal blooms. Nitrate ion, a minor component, is toxic to aquatic organisms but they [illegible]e very resistant to nitrate. [illegible]ivestock poisoning may occur from nitrite ingestion. It is recommended that the nitrate plus nitrit[illegible]trogen not exceed 10[illegible]m and that NO_2-N [illegible]ne not exceed 10 ppm.	TLV for NO is 25 ppm. TLV for NO_2 is 5.0 ppm. TLV for HNO_3 is 2.1 ppm. Odor perception at 0.12 ppm. Federal Primary Ambient Air Standard is 100 $\mu g/m^3$ (0.05 ppm) as an annual arithmetic mean.	National Interim Primary Drinking Water Standard for nitrate as nitrogen is 10 mg/ml. It has also been recommended that Nitrate-Nitrogen in drinking water not exceed 1.0 mmg/l.

*TLV = Threshold Limit Value. The concentration of a substance to which a worker can be exposed 8 hours per day or 40 hours per week without significant health effects or discomfort.

Source: Mitre Corp., 1976.

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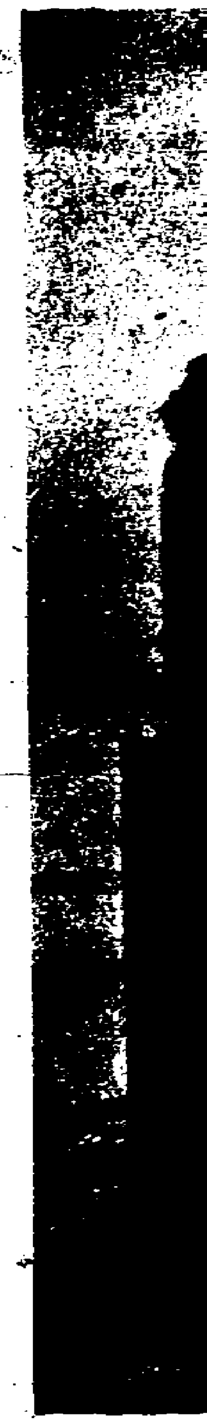
Health and Environmental Effe

Particulate Matter, Carbon Monoxide, and Carbon Dioxide

Fo[illegible] combustion is a major source of particles. Al[illegible]l combustion produces carbon [illegible] di[illegible]t substance, along with water, is the e[illegible]f efficient fossil fuel combustion.

Particles suspended in air can diminish visibility, cause substantial lung damage when inhaled, and can retard plant growth. Carbon dioxide in high concentrations can be harmful. The major concern with CO_2, however, is that excessive concentrations in the atmosphere may have a serious impact on the global climate.



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Effects of Energy Pollutants—Particles, CO and CO_2

Pollutant	Health Effects	Effects on Vegetation	Effects on Aquatic and Terrestrial Organisms	Air Standards	Water Standards
Particulate Matter	Particles 0.5 to 5.0μ in diameter are most likely to cause disease. Chronic symptoms due to lung scarring include: difficulty breathing, chest pain, cough, decreased vital capacity and heart disease.	Excessive dusting can clog the stomates of plant leaves, preventing air and water exchange.	Suspended solids harm aquatic biota by reducing light penetration, suffocating bottom dwellers, physical abrasion and habitat destruction. This is especially serious in nursery or spawning site. The following levels of suspended solids are recommended: <25 mg/l (high protection); 26-80 mg/l (moderate); 81-400 mg/l (low); over 400 mg/l (very low protection).	TLV* for nuisance particulates is 10 mg/m^3 total particulates. Primary National Ambient Air Quality Standard for Suspended Particulates is 75 μg/m^3 (annual), and 260 μg/m^3 (24 hr). The secondary standard is 60 μg/m^3 (annual) and 150 μg/m^3 (24 hr.).	
Carbon Monoxide CO	CO reacts with hemoglobin to form carboxyhemoglobin. May result in brain damage due to oxygen deprivation. Symptoms of exposure include: headache, dizziness, nausea, vomiting, systemic pain, cherry red skin color, and fatigue.	Plants are insensitive to CO levels known to affect man. At high concentrations the following symptoms are observed: leaf curling, increased aging, reduced gravity response, reduced leaf size, and feminization.	In water CO → CO_2. See next section for effects.	TLV = 50 ppm. National Primary Ambient Air Standard is: 10000 μg/m^3 for a yearly average, 40000 μg/m^3 for a 24 hr. average.	
Carbon Dioxide CO_2	CO_2 is not ordinarily considered a toxic gas. At high concentrations it stimulates respiration and breathing becomes labored. It forms carboxyhemoglobin and deprives the brain of oxygen. Symptoms of exposure include: headache, dizziness, tinnitus, difficulty breathing, muscle tremor, fatigue, and unconsciousness.	Plants require CO_2 for photosynthesis. High CO_2 concentrations may increase the acidity of rain, secondarily affecting vegetation.	Concentrations of free CO_2 rarely exceed 20 ppm in surface waters. Fish can acclimate to concentrations as high as 60 ppm but will try to avoid even minor increases in CO_2.	TLV = 5000 ppm.	

*TLV = Threshold Limit Value. The concentration of a substance to which a worker can be exposed 8 hours per day or 40 hours per week without significant health effects or discomfort.

Source: Mitre Corp. 1976.

Health and Environmental Effects

Hydrogen Sulfide and Radiation

Some geothermal energy activities release a significant amount of hydrogen sulfide. Hydrogen sulfide can be highly toxic to humans and other animals. Few organisms can exist where it is present in water. In air, its presence can be recognized by the odor of rotten eggs.

Although nuclear-powered electricity generation is carefully controlled, it is possible that radioactive materials can be emitted to the environment. For instance, the waste ore from which uranium has been milled must be well stabilized to assure that the remaining radioactive materials do not enter the biosphere. The same is true of the used fuel and other wastes from nuclear power plants, which must be carefully stored and guarded against potential sabotage. Exposure to nuclear radiation can cause cancer and a reduced life expectancy. Wild plants and animals also are affected and can absorb and accumulate such radioactive substances to hazardous concentrations.

Effects of Energy Pollutants – H_2S and Radioactivity

Pollutant	Health Effects	Effects on Vegetation	Effects on Aquatic and Terrestrial Organisms	Air Standards	Water Standards
Hydrogen Sulfide H_2S	H_2S is highly toxic. It is a pulmonary irritant but its major effect is paralysis of the nerves governing respiration leading to asphyxiation. Low level exposure may result in: fatigue, metallic taste, nausea, vomiting, diarrhea, pulmonary edema, eye irritation and dizziness. Chronic exposure can cause kidney, liver and/or brain damage.	At low concentrations little effect. At 20 to 40 ppm tan or white markings may appear on young, growing leaves.	H_2S is extremely toxic to aquatic organisms. A maximum level of dissociated hydrogen sulfide assumed to be safe for all aquatic organisms is 0.002 ppm.	TLV* = 10 ppm (skin) odor perception between 1 45 $\mu g/m^3$.	
Uranium	Exposure to the radiation from uranium can result in induction of leukemia, induction of neoplasms especially lung cancer, cataracts, reduced life expectancy, genetic effects, sterility and suppression of immune responses. Uranium especially accumulates in and affects lungs, bones, kidneys and liver.	Radiation affects plants in the following order of severity: tall plants (most severe), shrubs, hedges, mosses and lichens (least severe). Fields are generally more resistant to radiation effects than complex forest ecosystems.	Aquatic organisms often concentrate radioactive elements. In general the following order of sensitivity to radiation exists: large herbivorous mammals > small mammals and birds > herbivorous insects > filter feeding aquatic invertebrates > unicellular animals and plants.	For occupational exposure: U natural = 7×10^{-11} $\mu c/ml$. For nonoccupational exposure: U natural = 3×10^{-12} $\mu c/l$. Standards also exist for ^{230}U, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U and ^{240}U.	For occupational exposure: U natural = 5×10^{-4} $\mu c/ml$. For nonoccupational exposure: U natural = 2×10^{-5} $\mu c/ml$.

*TLV = Threshold Limit Value. The concentration of a substance to which a worker can be exposed 8 hours a day or 40 hours per week without significant health effects or discomfort.

Source: Mitre Corp., 1976.

Sulfates in Air

A Serious Health Problem

The complex relationship between sulfur dioxide emissions and sulfates in the atmosphere is currently under intensive study. The rate at which SO_2 from power plant stacks is converted into sulfates in the air is affected by the presence of other air pollutants such as nitrogen oxides, hydrocarbons, and adsorbent particles and by weather conditions. It is known that sulfur oxide emissions from fossil fuel combustion can travel long distances, being converted to sulfates in the process and possibly exposing populations and ecosystems a hundred or more kilometers from the original source. As a result, several areas of high population are exposed to significant sulfate concentrations.

Mechanisms that Convert Sulfur Dioxide to Sulfates or Sulfuric Acid Aerosols

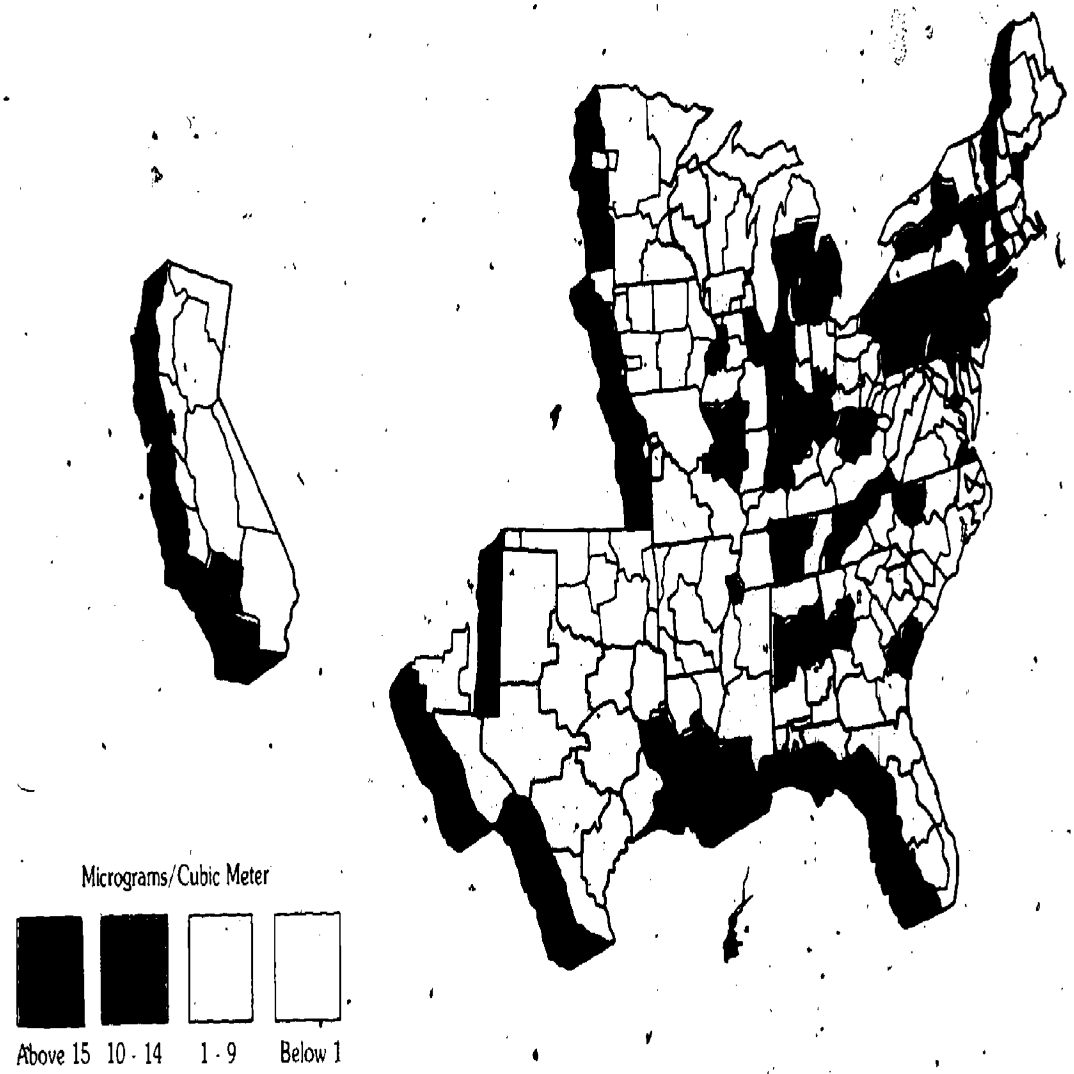
Mechanism	Factors on which sulfate formation depends
Direct photo-oxidation	Sunlight intensity
Indirect photo-oxidation	Organic oxidant concentration, OH, NO_X
Air oxidation in liquid droplets	Ammonia concentration
Catalyzed oxidation in liquid droplets	Concentration of heavy metal (Fe, Mn) ions
Catalyzed oxidation on dry particles	Carbon particle concentration (surface area)

Health Effects of Aerosol Acid Sulfates

Effect	Threshold concentration ($\mu g/m^3$)	Duration of exposure
Increased daily mortality (four studies)	25	24 hours or longer
Aggravation of heart and lung disease in elderly (two studies)	25	24 hours or longer
Aggravation of asthma (four studies)	6-10	24 hours or longer
Increased acute respiratory diseases in children (four studies)	13	Several years
Increased risk of chronic bronchitis		
Cigarette smokers	15	Up to 10 years
Nonsmokers	10	Up to 10 years

Source: CEQ, 1975.

Sulfate Pollution
Concentrations, 1974



Source: Adapted from Teknekron, 1977.

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Accidents and Non-nuclear Energy

Underground Mining Leads in Hazards

Non-nuclear energy sources are prone to various types of accidents resulting in injuries and deaths. The facing charts, while they do not include long-term health impacts (e.g., black lung disease), clearly indicate that underground coal mining is the most hazardous method of extracting fuels for energy. Much eastern coal is extracted from underground mines.

Several estimates have been made of the probabilities of, and potential damage from, nuclear energy operations. These estimates vary widely. They are not presented here because of the complexities of the assumptions involved and the difficulty in presenting the data in a consistent and comparable manner.

Annual Deaths and Injuries by Energy Source for a 1000 Megawatt Power Plant with a Load Factor of 0.75 (Per Unit Energy)

	Coal		Crude Oil			Natural Gas
	Deep	Surface	Onshore	Offshore	Import	Total
Fatalities	4.00	2.64	0.35	0.35	0.06	0.02
Injuries	112.30	41.20	32.30	32.30	5.70	18.30

LNG Risk Analysis-Fatalities per Million Years

Model	Los Angeles		Oxnard		Pt. Conception	
	Marine	Terminal	Marine	Terminal	Marine	Terminal
Federal Power Commission		100	1		10	
Science Applications, Inc.	0.1	0.1	0.01	0.1	0.001	0.1
El Paso Alaska Company					0.01	

Coal Mining Accident Rates

	Disabling Injuries / Million Employee-Hours
Underground Coal Mining	35.0
Surface Coal Mining	10.0
Overall Industry Average (All member companies of National Safety Council)	9.8

Types of Coal Mining Accidents

Accident	Percentage (%)
Underground (total)	80
Roof, rib, and face falls	50
Fires and explosions	10-12
Transportation (coal haulage)	16-15
Surface (total) (Fall of highwall, equipment misoperation, electrical system malfunctions)	20

Oil Industry Accident Data

	Accidents/year	Fatalities/year	Injuries/year
Shipping	636	76	37
Blow-outs	11	*	*
Offshore rigs	5	6	*
Pipelines	135	1	1
Refineries	*	3	5915

*Unknown

Source: U. S. EPA, 1977

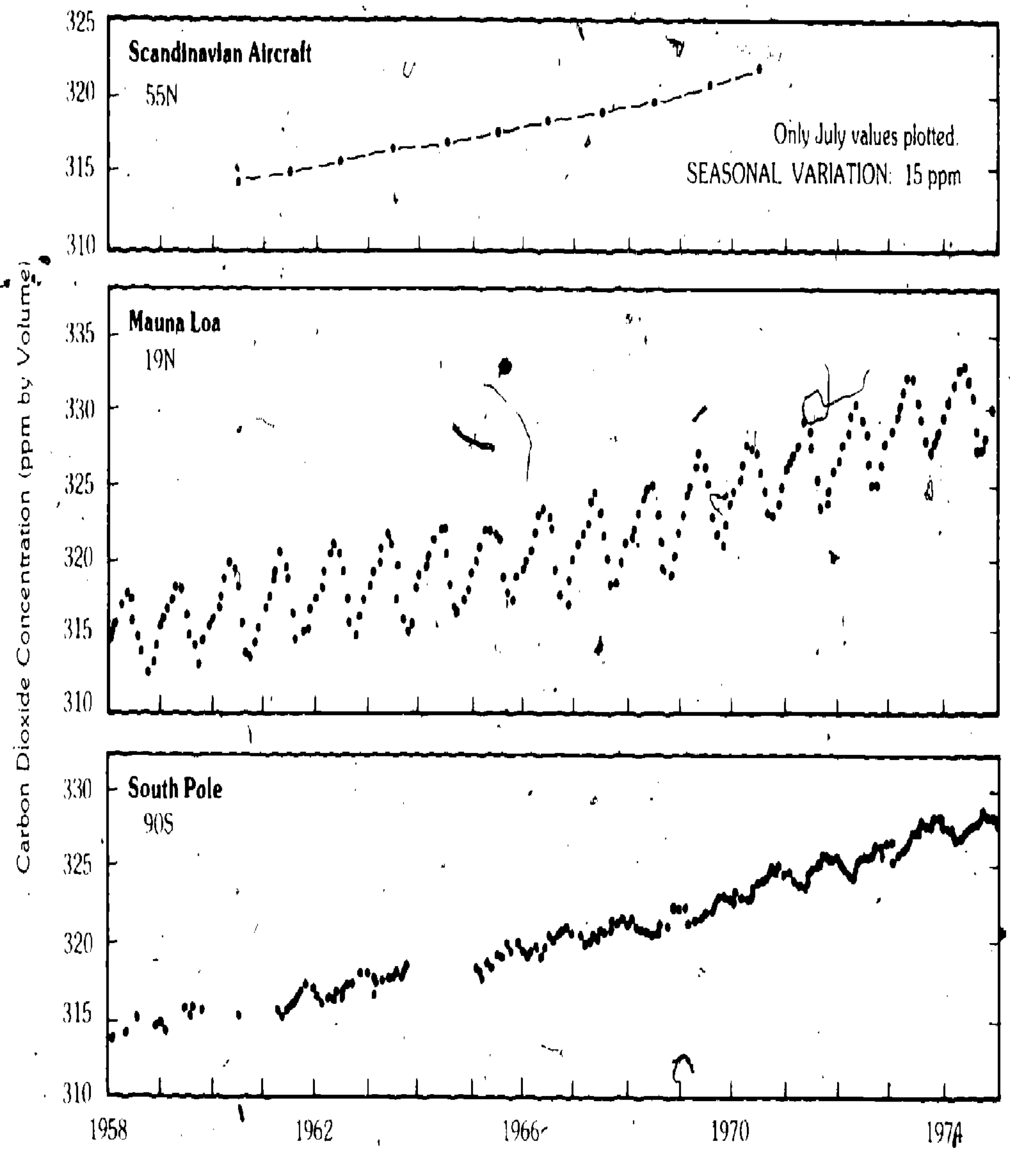
CO_2 from Fossil Fuels

A Potential Global Impact

One of the by-products of most energy use on earth—from coal combustion in power plants to food digestion by humans—is carbon dioxide gas. Since the industrial revolution, increasing use of fossil fuels has emitted increasing amounts of carbon dioxide (CO_2) into the atmosphere.

Some monitoring studies indicate a gradual global increase in the CO_2 concentration. Extensive research efforts are beginning to determine what effect such an increase could have on the environment. Some theories predict that this increase in CO_2 concentration in the atmosphere may serve to trap heat and cause a potentially disastrous increase in global temperatures—the 'greenhouse effect.' This theory and others are currently under study.

Atmospheric Concentration of Carbon Dioxide



Source: U.S. Congress, 1976

Regional Issues

Introduction

Each geographic region has its own particular energy-related environmental concern. Some major regional concerns are: mining land disturbance in eastern and western coal areas, water requirements for energy development in the west, acid rainfall in the east and oil spills in coastal areas.

Contents

Coal and the Land

Differences Between East and West

In order to strip mine coal, the dirt above the coal seam (overburden) must be removed. This disturbance causes erosion and acid drainage in the water-plentiful eastern areas and revegetation difficulties in the water-poor western areas.

Eastern coal fields, in general, have thinner seams and are located on greater average slopes than are western fields. These factors result in greater surface disturbance per ton of surface-mined eastern coal. Western areas, with thicker seams and gentler slopes, show less surface disturbance per ton of coal mined.

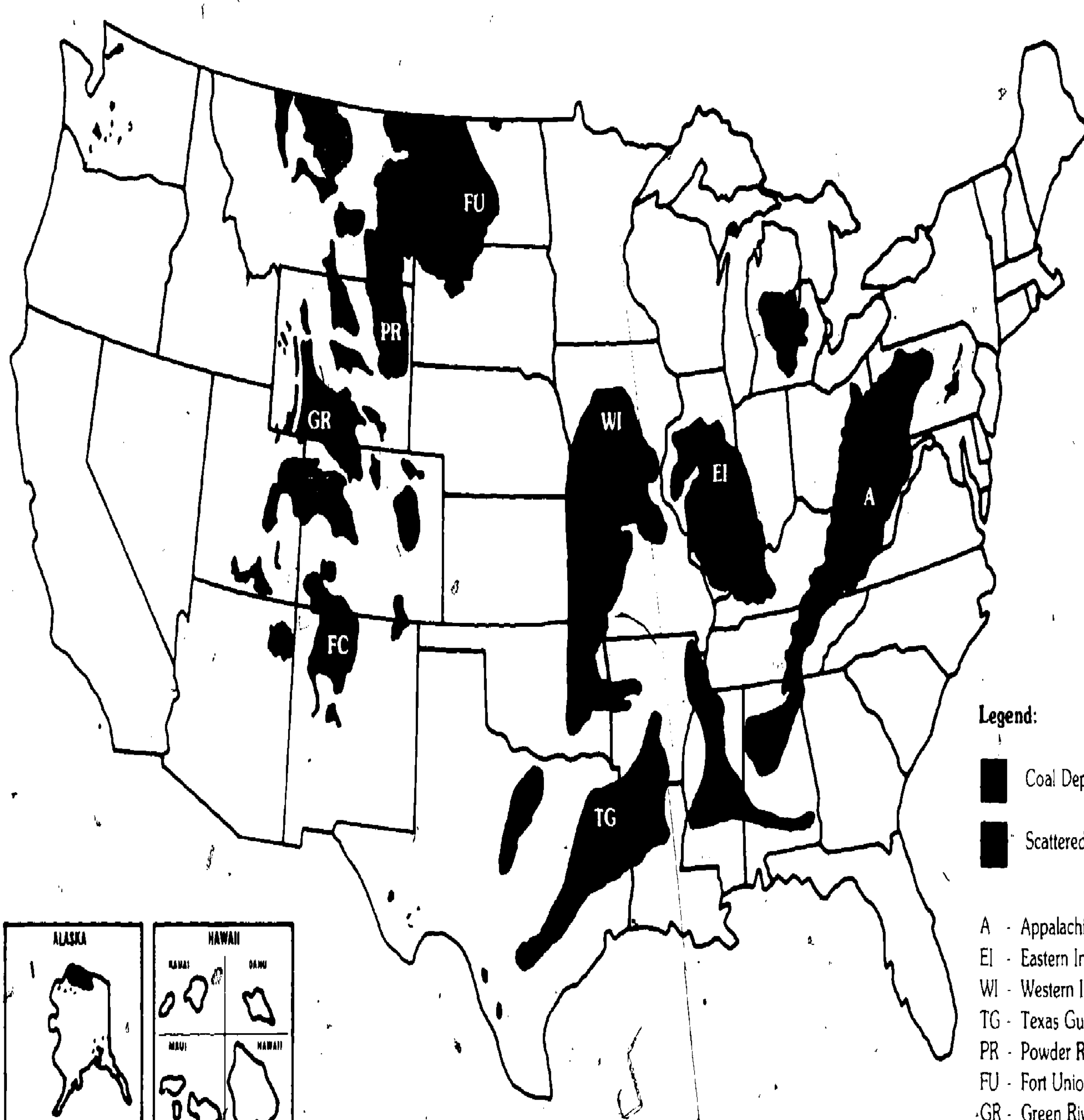
Land Disturbed per Million Tons of Surface Coal Mined[1]

	Appalachia	Eastern Interior	Western Interior	Texas Gulf	Powder River	Fort Union	Green River	Four Corners
Average Seam Thickness (ft)	6.0	5.5	5.5	8.0	26.0	10.0	8.0	8.0
Acres per 10^6 Tons	95	104	104	71	22	57	71	71

[1] Numbers based on 1750 tons per acre-ft

Source: U.S. ERDA, 1977c.

Coal Deposits in the United States



Source: Adapted from U. S. Geological Survey, 1975.

Legend:

Coal Deposits

Scattered Coal Deposits

A - Appalachia
EI - Eastern Interior
WI - Western Interior
TG - Texas Gulf
PR - Powder River
FU - Fort Union
GR - Green River
FC - Four Corners

The Thirsty West

A Large Demand Versus a Limited Supply

During periods of low water flow, energy will compete with food production and other uses for scarce water supplies. The chart opposite is an estimate of water resources potentially available for energy development in the upper Colorado River Basin. The graph depicts one possible future allocation of these resources to competing uses.

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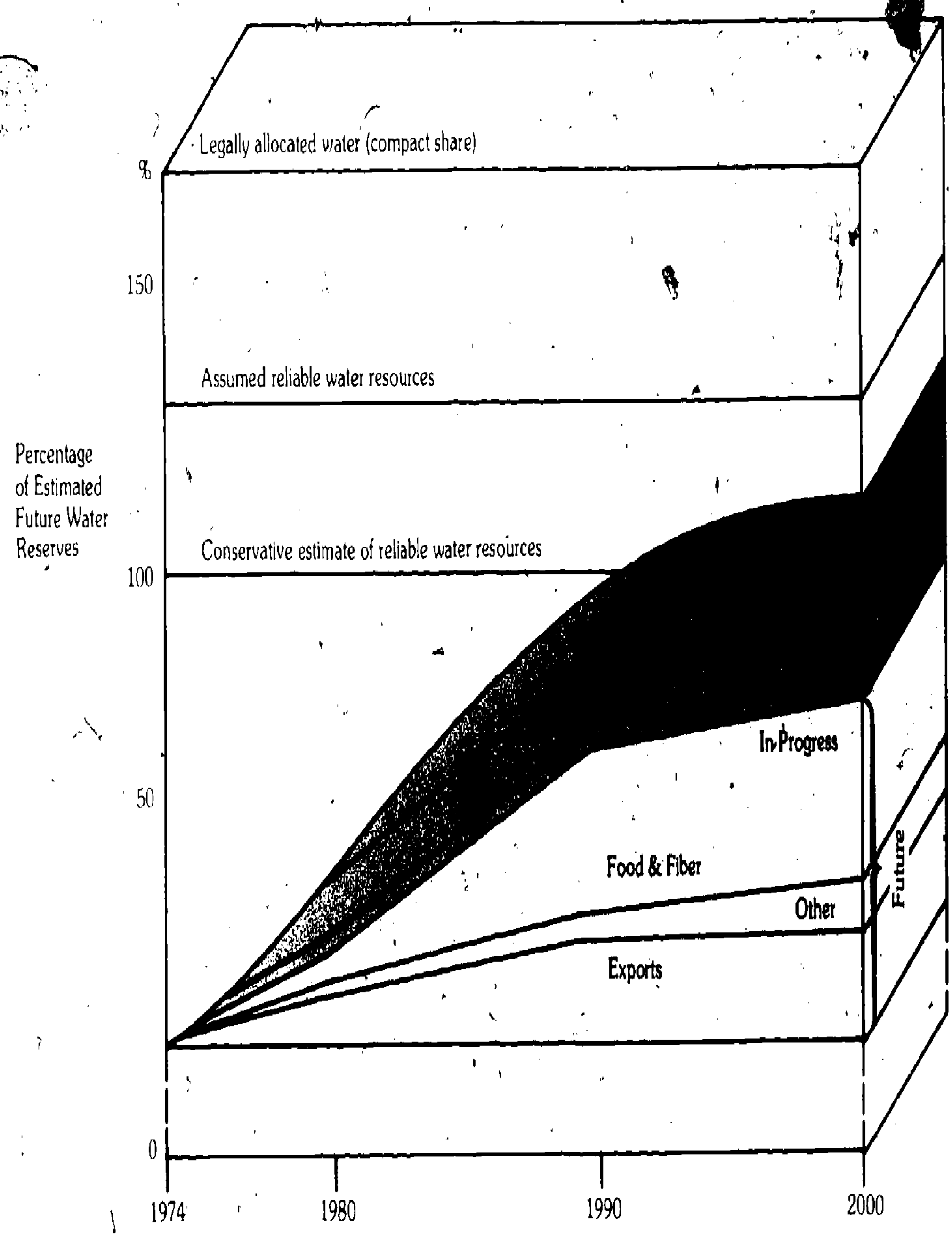
Water Available for Future Development in Upper Colorado River Basin



Note: Chart does not indicate water resources already committed.
Source: Roach, undated.

Coal Slurry Pipelines

One-way Water Routes

Coal slurry pipelines are being considered as an alternative to coal shipment by railroad in many locations. These pipelines would extend from the coal source and terminate at user locations. The coal would be pulverized, mixed with water, and then pumped through the pipelines. The water supply at the slurry's source locations is of primary importance. Coal slurry transport requires approximately one ton of water to transport one ton of coal. Approximately one acre-foot of water is required to transport 1400 tons of coal.

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Coal Slurry Pipeline Water Requirements

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mbers indicate annual water requirements in acre ft./yr.
Source: Adapted from Wasp, 1975.

Alternatives for Western Coal

Choice of Site Determines Pollutant Impact

For increasing western coal production, different alternatives such as shipping the coal to the midwest, mine-mouth power plants, and coal conversion will each have different environmental problems. Among the considerations to be weighed are the:

- pollutants produced
- solid wastes generated
- land disturbances and reclamation requirements
- water requirements
- secondary impact—mining towns, roadways, water and waste treatment/disposal requirements, etc.

Environmental Problems Across Alternative Fuel Cycles[a]

Fuel Cycle	Air emissions, in thousands of pounds/day			Solid waste, in thousands of tons/day[b]	Land use, in thousands of acres[c]	Water required, in millions of gallons/day	Occupational health, in thousands of man-days lost/year	Primary product efficiency (in percent)
	Particles	SO_2	HC					
Mine mouth								
Surface coal mine (Montana)	55	0	0	0	5	0	3	100
Coal-fired powerplant (mine mouth)	16	3,244	37	10	13	138	5	37
Long distance transmission (Chicago)	0	0	0	0	161	0	NA	92
Total for scenario	216	3,245	38	10	179	128	NA	34
Montana gasification								
Surface coal mine (Montana)	73	1	2	0	7	0	4	100
Low BTU gasification (mine mouth)	0	41	4	16	9	22	22	76
Low BTU gas powerplant (mine mouth)	44	269	3	0	5	138	5	37
Long distance transmission to Chicago	0	0	0	0	161	0	NA	92
Total for scenario	117	312	9	16	182	150	NA	26
Rail haul								
Surface coal mine (Montana)	51	1	1	0	4	0	3	100
Rail to Chicago	40	91	44	1	36	0	22	99
Coal-fired powerplant (Chicago)	147	2,976	34	9	10	117	5	37
Total for scenario	238	3,068	80	10	50	117	30	37

Fuel Cycle	Air emissions, in thousands of pounds/day Particles	SO₂	HC	Solid waste, in thousands of tons/day[b]	Land use, in thousands of acres[c]	Water required, in millions of gallons/day	Occupational health, in thousands of man-days lost/year	Primary product efficiency (in percent)
Slurry pipeline								
Surface coal mine (Montana)	52	1	1	0	5	0	3	100
Slurry pipeline to Chicago	0	0	0	0	28	32	NA	98
Coal-fired powerplant (Chicago)	147	2,976	34	9	10	117	5	37
Total for scenario	199	2,977	36	9	42	149	NA	36
Chicago gasification								
Surface coal mine (Montana)	67	1	2	0	6	0	4	100
Rail to Chicago	52	120	59	2	47	0	29	99
Low BTU gasification (Chicago)	0	38	4	14	9	20	20	76
Low BTU gas powerplant (Chicago)	40	247	3	0	4	117	5	37
Total for scenario	160	406	67	17	67	137	58	28
Omaha generation								
Surface coal mine (Montana)	70	1	1	0	6	0	4	100
Rail to Omaha	27	63	31	2	25	0	30	99
Low BTU gasification (Omaha)	0	39	4	15	9	21	21	76
Low BTU gas powerplant (Omaha)	42	257	3	0	2	122	5	37
Long distance transmission to Chicago	0	0	0	0	77	0	NA	96
Total for scenario	140	360	39	17	119	143	NA	27

NA = Not available.

[a] Totals may not add because of rounding.

[b] The solid wastes associated with rail haul result from coal dust blown off the rail cars.

[c] Includes all the land in the transmission right-of-way; only a portion of the right-of-way land for the slurry pipeline because the land may be used for other purposes when the pipeline is buried; and the portion of railroad right-of-way equal to the portion of the total railroad capacity that would be taken up by coal trains.

Source: Adapted from Radian Corporation, 1975.

Alternative Uses of Western Coal

Environmental Scenarios for Electricity, Synthetic Fuels

In addition to environmental impacts resulting from western and midwestern energy extraction and processing, the end use of the products will result in additional problems. Different end-use scenarios indicate the potential nationwide impacts of various alternatives.

Alternative Energy Systems in the West and Midwest

End use	Air emissions (pounds/hours)					Solid waste (tons/day)	Land use (acres)	Water required (MGD)	Energy efficiency (percent)
	Particles	SO_x	NO_x	CO	HC				
Electricity									
Surface coal mine (Montana)									
Rail to Chicago									
Coal-fired powerplant (Chicago)									
Total for scenario	9,919	127,812	106,707	15,527	3,329	10,480	50,311	117	36
Surface coal mine (Montana)									
Slurry pipeline to Chicago									
Coal-fired powerplant (Chicago)									
Total for scenario	8,290	124,033	84,950	4,973	1,482	9,130	41,992	149	36
Surface coal mine (Montana)									
Rail to Chicago									
Low BTU gasification (Chicago)									
Low BTU gas powerplant (Chicago)									
Total for scenario	6,671	16,907	99,912	16,321	2,776	16,230	66,640	137	28
Surface coal mine (Illinois)									
Low BTU gasification (mine mouth)									
Long distance transmission to Chicago									
Total for scenario	14,416	65,736	72,803	2,532	302	20,203	79,101	140	28
Oil well (Gulf coast)									
Pipeline to Chicago									
Refine (Chicago)									
Oil-fired powerplant (Chicago)									
Total for scenario	1,284	24,743	89,129	4,081	11,400	9,940	25,708	161	33

End use	Air emissions (pounds/hours)[1] Particles	SO_X	NO_X	CO	HC	Solid waste (tons/day)	Land use (acres)	Water required (MGD)	Energy efficiency (percent)
Liquid fuels									
Surface oil shale mine (Colorado)									
Retort (mine mouth)									
Crude pipeline to Chicago									
Refine (Chicago)									
Total for scenario	1,923	6,099	4,541	858	6,016	185,362	20,135	38	68
Surface coal mine (Montana)									
Liquefaction (mine mouth)									
Crude pipeline to Chicago									
Refine (Chicago)									
Total for scenario	2,804	3,309	13,549	1,333	7,475	6,792	15,218	57	52
Oil well (Gulf coast)									
Crude Pipeline to Chicago									
Refine (Chicago)									
Total for scenario	427	1,029	2,041	597	3,154	3	7,725	11	93
Surface coal mine (Illinois)									
Rail to Chicago									
Liquefaction (Chicago)									
Refine (Chicago)									
Total for scenario	8,359	4,353	15,725	2,316	7,657	11,148	32,368	57	47
Gas									
Surface coal mine (Montana)									
High BTU gasification (mine mouth)									
Gas pipeline to Chicago									
Total for scenario	2,780	3,876	19,199	6,272	1,148	5,560	9,827	64	65
Surface coal mine (Illinois)									
High BTU gasification (mine mouth)									
Gas pipeline to Chicago									
Total for scenario	6,073	10,424	8,017	618	165	7,930	15,252	64	61
Gas well (Gulf coast)									
Gas pipeline to Chicago									
Total for scenario	52	166	2,090	59	81,700	0	16,892	0	96

[1] On the basis of a 10^{12} BTU per day output from the trajectory.

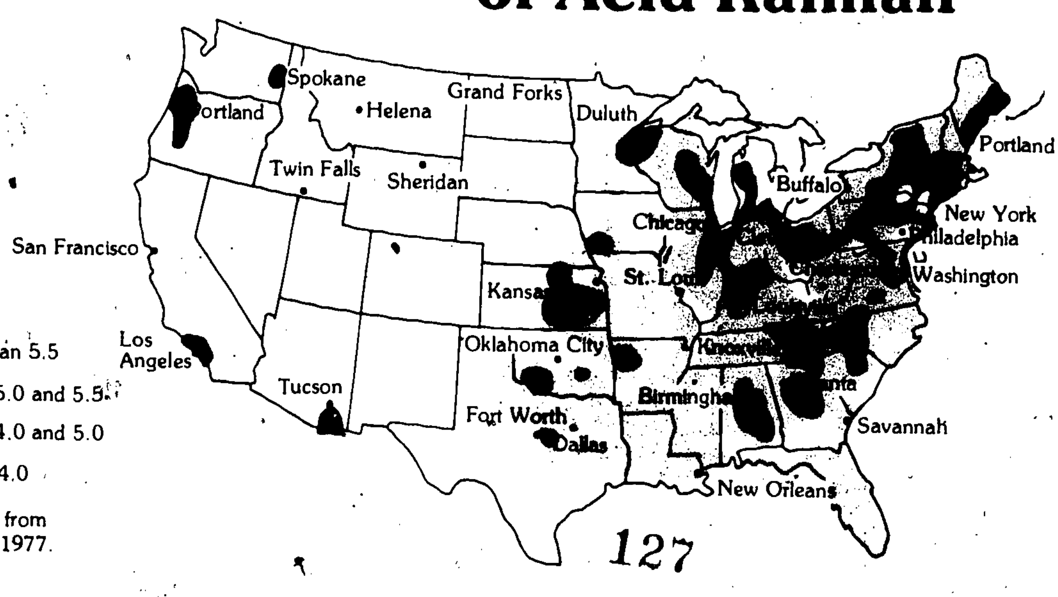
Source: Adapted from Radian Corp., 1975.

Acid Rainfall

A Problem in the East

Burning of fossil fuels has increased the concentration of sulfur dioxide and sulfates in the atmosphere. These pollutants contribute to the acidity of rainfall that degrades health and water quality, affects specific life forms and damages property. Studies are currently being conducted on the atmospheric effects of relatively long-range movement of pollutant emissions from the midwest and Great Lakes region to the northeast or into Canada. Acid rains harm crops, fish, and timber, and also damage building materials, outside stone and concrete work, and some metallic equipment.

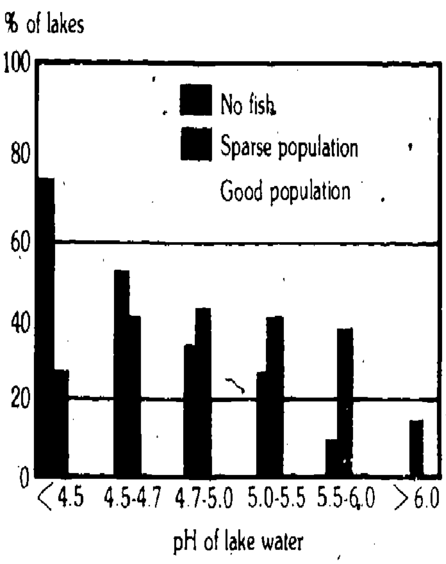
Regional Impact of Acid Rainfall



- pH greater than 5.5
- pH between 5.0 and 5.5
- pH between 4.0 and 5.0
- pH less than 4.0

Source: Adapted from U. S. Congress, 1977.

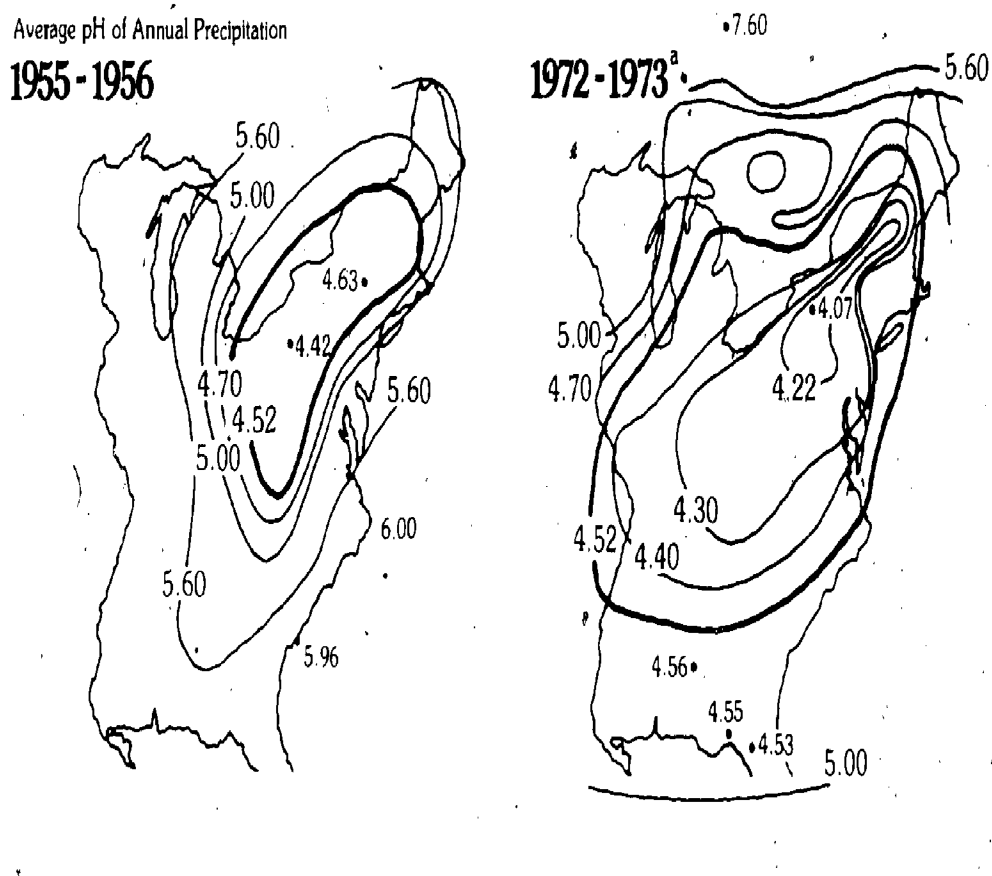
Fish Population Declines as the Acidity of Lake Water Increases



Note: Status of fish in 1,679 lakes in four counties in southwestern Norway.

Acidity of Precipitation has Increased Markedly in the Eastern U. S. . . .

Average pH of Annual Precipitation



Source: Adapted from Likens, 1976.

Oil in the Ocean

An International Problem

Oil pollution at sea comes from a number of sources. More than 50% of this pollution can be attributed to river and urban runoff, atmospheric fallout, and natural seepage. Spills associated with the production and transport of oil account for most of the rest.

The following statistics relate to oil in the marine environment:

- Approximately 12,000 oil spills occur annually.
- Seventy-five percent of human-caused spills come from ships.
- The number of tanker spills does not appear to depend primarily upon size or age of the tanker, but upon the number of voyages.
- Offshore oil production accounts for approximately 2,000 barrels of spilled oil per year.
- Spills of oil cost approximately $1,000/barrel to clean up.

Sources of Oil in the Oceans

Source	Estimated Contribution (Barrels/Yr)	(%)
Production and Transport	16,000,000	34.9
Tankers		
Dry Docking		
Terminal Operations		
Bilges		
Accidents		
Direct Sources	6,500,000	14.3
Coastal Refineries		
Municipal Waste		
Industrial Waste		
Off-Shore Oil Production		
Indirect Sources		
River and Urban Runoff	14,000,000	31.2
Atmospheric Fallout	4,500,000	9.8
Natural Sources	4,500,000	9.8
Seepage		
TOTAL	45,500,000	100.0

Source: U. S. EPA, 1977 f.

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For Further Reading

Interagency Energy/Environment Research and Development Program – Status Report III, EPA-600/77-032, by the Office of Energy, Minerals and Industry, Office of Research and Development, Environmental Protection Agency (April 1977).

A detailed status report of the Interagency Program including history, organization, and the basic rationale for the Program. Some cost figures are given for environmental control technologies being developed and for health and environmental effects studies of energy use.

Energy/Environment II, EPA-600/9-77-012, by the Office of Energy, Minerals, and Industry, Office of Research and Development, U S. Environmental Protection Agency. (November 1977).

A summary of the proceedings of the second national conference of the Interagency Energy/Environment Programs. this report presents an overview and status of the Program. Principal topic areas addressed are: fuel processing, power generation for utilities and industry, extraction and beneficiation of fuels, integrated technology assessment, health effects of pollutants, atmospheric transport of pollutants, measurement and monitoring of pollutant discharges, and ecological effects.

A National Plan for Energy Research, Development and Demonstration, ERDA 77-1, by the U.S. Energy Research and Development Administration (June 1977).

This brief, easily readable report presents the federal research and development program for energy development It addresses a broad range of topics including: the role of energy conservation, expansion of existing fuel sources, new types of fuels (shale oil, geothermal, solar, fuel from wastes, etc.), nuclear energy, and environmental safety [illegible]rch.

Western Energy Resources and the Environment: Geothermal Energy. EPA-600/9-77-010, by the Office of Energy, Minerals and Industry, Office of Research and Development, U.S. Environmental Protection Agency. (May 1977).

This document defines the extent and potential of geothermal resources, the technology available for development, and the constraints to growth. It highlights major research and development efforts being carried out by ERDA, EPA, and other federal agencies. The report aims to provide the reader with a balanced picture of the problems as well as prospects for the development of geothermal energy in the United States, and is intended to be a general reference for use by policy-makers and the interested public.

Geothermal Industry Position Paper, EPA-600/7-77-092. By EPA Geothermal Working Group, Office of Research and Development, U.S. Environmental Protection Agency, (August 1977).

The environmental impact of geothermal energy development may be less intense or widespread than that of some other energy sources; however, it is the first example of a number of emerging energy technologies that must be dealt with by EPA. EPA may consider a spectrum of options ranging from a posture of business-as-usual to one of immediate setting of standards. The paper discusses the regulatory approaches and the potential problems that geothermal energy may present in the areas of air quality, water quality, and other impacts.

Oil Shale and the Environment, EPA-600/9-77-033, by the Office of Energy Minerals, and Industry, Office of Research and Development, U.S. Environmental Protection Agency. (October 1977).

There is an urgency to produce more domestic oil as existing supplies dwindle and world oil prices rise. But what we know about the environmental consequences of oil shale development is sparse and often speculative. However, we do know that a relatively small region of the country will have to bear the full burden of these environmental consequences. Two issues become basic to the future of oil shale: Should the resource be developed now with all of the attendant environmental risks, or can we afford to wait until we find out more about the risks and their prevention?, and: Is it fair to trade local lifestyle for the national good?

The purpose of this report is to put oil shale development into a realistic environmental perspective and to describe what the government is doing to insure that development does not exact an intolerable environmental price.

A Practical Approach to Development of a Shale Oil Industry in the United States, prepared by Colorado School of Mines Research Institute, P.O. Box 122, Golden, Colorado 80401. Prepared for Gary Operating Company, Four Inverness Court East, Englewood, Colorado 80110. (October 1975).

A technically accurate and easily readable report concerning all phases of the oil shale industry. This study puts forth a well-reasoned proposal that the oil shale industry should be developed in a gradual, orderly manner instead of under a crash program. The idea has considerable merit from environmental and financial standpoints. The report was summarized as a Position Paper presented to the Committee on Science and Technology, U.S. House of Representatives regarding the 1976 ERDA Authorization Bill, H.R. 3474 (5.598).

Synthetic Liquid Fuels Development: Assessment of Critical Factors, ERDA-76-129/2, by the Stanford Research Institute, 333 Ravenswood, Menlo Park, California 94025. Prepared for the Office of Energy, Minerals and Industry of the Office of Research and Development, Environmental Protection Agency and for the Division of Transportation Energy Conservation, Energy Research and Development Administration. (May 1976).

A definitive study of the environmental, societal and institutional ramifications of synthetic fuels development. The study was organized as a technology impact assessment and called on a large team of experts to contribute in their specialty area. There are 23 separate chapters covering everything from the legal mechanisms for access to oil shale and financing the synthetic liquid fuels industry to the impact of industrial growth on rural society. Each chapter can stand alone for easy reading.

Advanced Fossil Fuels and the Environment, EPA-600/9-77-013, by the Office of Energy, Minerals and Industry, Office of Research and Development, U.S. Environmental Protection Agency. (June 1977).

This report reviews the environmental control technologies being developed in concert with advanced fossil fuel conversion processes. These control technologies are designed to eliminate the adverse health and ecological effects that are often by-products of energy conversion.

While specific fuel conversion processes are examined in this report, it is emphasized that EPA's major interest lies with the type and quality of pollutants from the processes and the practicality and effectiveness of pollutant control methods.

With its involvement in the actual conversion process, however, EPA is striving to assure that the new and evolving conversion processes will be environmentally sound as well as efficient. In addition, the Agency is working to prevent pollution from conversion processes already developed and in use.

Coal Cleaning with Scrubbing for Sulfur Control: An Engineering/Economic Analysis, EPA 600/9-77-017, by the Office of Energy, Minerals and Industry, Office of Research and Development, U.S. Environmental Protection Agency. (August 1977).

The sulfur content of many U.S. coals can be significantly reduced by pre-combustion "cleaning", using established techniques widely employed to remove rock and other noncombustible constituents of coal. This approach to sulfur reduction may be used as an adjunct to flue gas cleaning ("scrubbing") as a means of reducing the sulfur emissions. This study examines the economics of using coal cleaning in addition to scrubbing in some 48 cases, as opposed to using scrubbing alone.

Nuclear Power Issues and Choices, by the Nuclear Energy Policy Study Group, Spurgeon M. Keeney, Chairman. Sponsored by the Ford Foundation and administered by The MITRE Corporation. Ballinger Publishing Company, Cambridge, Mass. (January 1977).

A general overview and a detailed analysis of major issues relating to the current and future status of nuclear power development and utilization. In addition to addressing such essential considerations as fuel supplies, economics, and competitiveness of nuclear and other power sources, the report also addresses such controversial issues as health and environmental effects, long-term management of radioactive wastes, nuclear terrorism, and proliferation of nuclear weapons.

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