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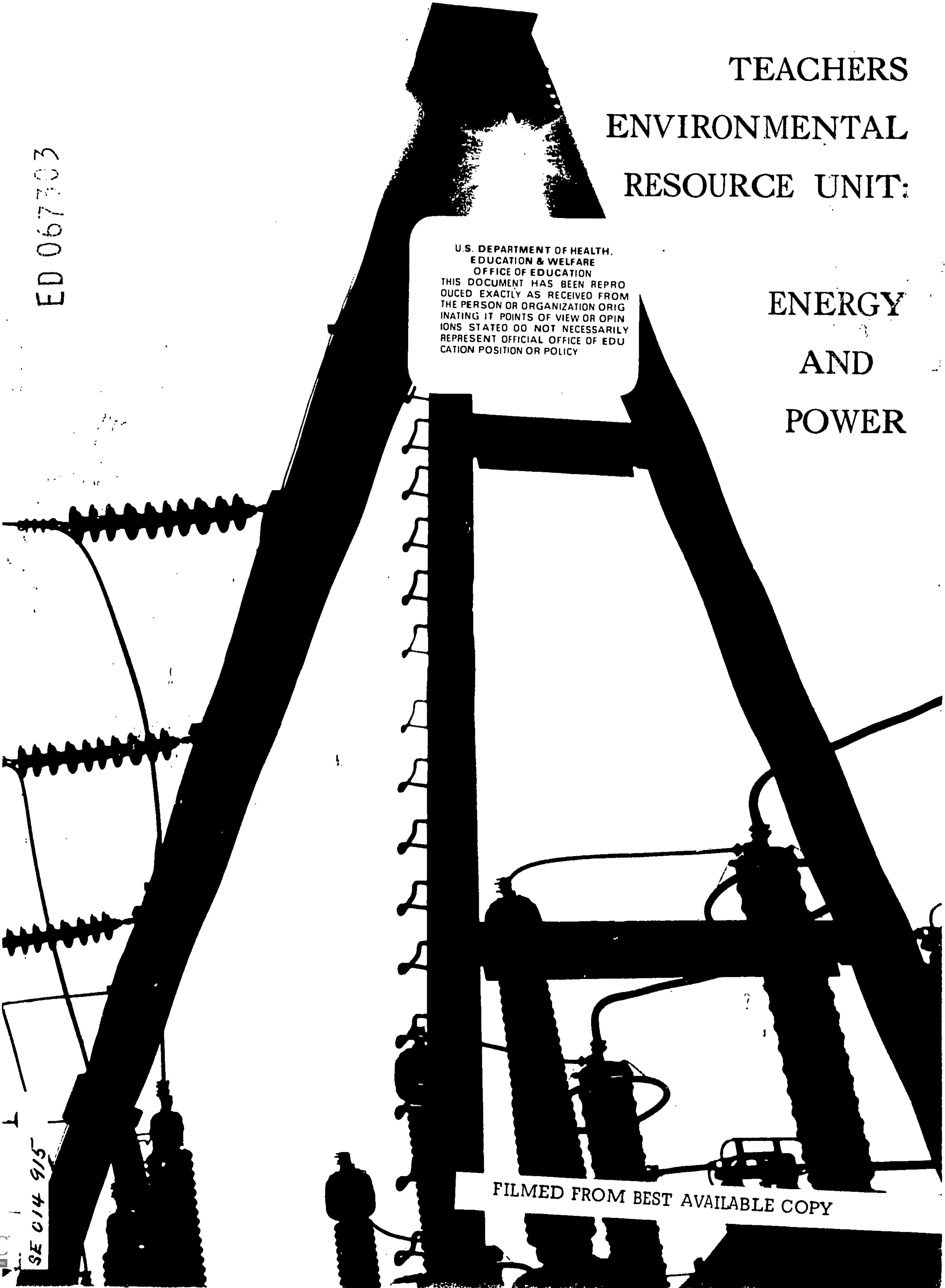
ABSTRACT

Problems associated with energy production and power are studied in this teacher's guide to better understand the impact of man's energy production on the environment, how he consumes energy, and in what quantities. The resource unit is intended to provide the teacher with basic information that will aid classroom review of these problems. Topics focus on solar energy, man and energy, energy efficiency, fossil fuel consumption and pollution, nuclear energy, geothermal energy, superconductivity, magnetohydrodynamics, and waste recycling. A bibliography is included. This work was prepared under an ESEA Title III contract for the project "Broad Spectrum Environmental Education Program." (BL)

TEACHERS ENVIRONMENTAL RESOURCE UNIT:

ENERGY AND POWER



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TEACHERS ENVIRONMENTAL RESOURCE UNIT:

ENERGY AND POWER

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INTRODUCTION

In 1960 the United States looked hopefully toward a decade of prosperity and development based on its capacity for energy production. At that time the word ecology was seldom mentioned. Yet a short ten years later it was apparent that the environment was in danger. Earnest speakers at Earth Day observances warned that mankind had entered an environmental and demographic crisis that would soon end in disaster if appropriate steps were not taken. Many countered that such warnings were unwarranted passing obsessions. The debate continues, but it is becoming increasingly apparent that the answer is somewhere in between. What is required is education to promote better understanding of the problems that exist.

Sober research over the past few years tells us that doomsday is not so close as some originally perceived it, but if we project the quickened growth patterns following World War II to the end of the century we do indeed have the makings of a crisis. As one author states, "It is a crisis because it will be difficult, in so short a period to effect stopgap technical cures for the fast deteriorating environment and even more difficult to alter basic human attitudes toward reproduction and economic achievement..."

Our youth must therefore begin to take part in a careful examination of the process of economic and social change that increased awareness of critical environmental needs has brought about. This resource unit is intended to provide basic information in support of this examination. As it is written new ideas are being generated and new data is being published. What economic decisions transpire even on a daily basis will add new insight to the information contained in the unit. But we must choose a point to begin.

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I. OVERVIEW

A. SOLAR ENERGY

The sun is the primary source of energy that supports life on earth. This energy is in the form of electromagnetic radiation and can be described in terms of watts (units of electrical energy). The sun produces approximately 3.8×10^{26} watts of power every second. This figure corresponds to approximately 9.1×10^{25} calories (units of heat energy). The earth receives about 1.3×10^{24} calories of energy from the sun each year, but a good deal of this energy never affects the environment of the earth.

Close to 50 per cent of the solar energy incident upon the earth is reflected back into space by clouds and atmospheric dust. Another 15 per cent is reflected from the surface by the oceans, snow, sand and forested land. Of the 35 per cent of retained solar energy, some is used immediately to evaporate water and lift it into the atmosphere, and consequently affects the heat balance of the earth. Most of this energy is absorbed by land and marine vegetation. Only 5.3 per cent is absorbed directly by bare soil. Through the processes of death and decay the largest portion of retained solar energy is stored in deposits under the earth's surface. Energy that is stored underground has an effect on the earth's heat balance as it is reradiated back into space and interacts with atmospheric gases such as carbon dioxide and water vapor at low altitudes. This is the so-called greenhouse effect and contributes significantly to the heating of the lower atmosphere.

B. ENERGY AND MAN

1. Nutritional Energy Needs

Man is a recipient of solar energy as it affects the life processes of his environment. All of life is delicately interrelated and balanced according to the solar energy supply. In order to stay alive man consumes nutritional energy from the food chain. How he consumes this energy, and in what quantities, is of great importance. For example, eating meat is a less efficient method of meeting nutritional energy needs than a vegetation diet.

One author argues that given the present world population, if all of our food consisted of vegetation then the calories required to support the human race would be provided by about 1/250 of the total amount of plant matter produced each year. If the diet of the world consisted primarily of meat we would consume ten times the vegetation required to support us because herbivores retain on the average only about 10 per cent of the biomass they eat.[1] Considerations such as this must certainly be a factor as attempts are made to cope with world hunger problems. The situation is not yet this extreme, but expanding populations that consider large quantities of meat essential to a healthy diet do have an impact on total land resources.

2. External Energy Needs

Some of the energy used to meet external needs is recovered in the form of waterpower. Hydrogeneration accounts for about 2 per cent of world energy consumption. In Europe, about 23 per cent of available water is utilized, in North America about 22 per cent. In most of the underdeveloped countries the figure is below 5 per cent. Most of the energy used to support modern industrial activity is obtained from the solar energy that has been stored and converted into fossil fuels.

The substantial increase in power production since the beginning of the Industrial Revolution, coupled with the polluting effects of fossil fuels is at the heart of the current examination of the capabilities and ultimate goals of modern technology. World energy consumption has been doubling approximately every twenty years. In the United States energy consumption has been doubling every fourteen years since 1940.

Energy used to meet external needs can be simply divided into electrical and non-electrical forms.

a. Electrical Energy

Electricity is used in the home to run everything from kitchen appliances and heaters to lawn mowers and other garage tools. Industrially it is used in transportation facilities, heating and lighting, in the production of chemicals, textiles, plastics and many other products.

Although natural gas, oil, and water are used to generate electricity, coal is the primary fuel. Total U. S. consumption of coal in power generation rose from about 50 million tons in 1940 to over 300 million by 1970.

Electrical energy consumption in the United States has doubled approximately every ten years to a point where it now accounts for about one-fifth of the total energy consumed. The annual growth rate is a little more than 7 per cent. Since the population growth rate is 1 per cent, per capita electrical energy consumption is increasing at about 6 per cent a year. At this rate, even allowing for some slowdown in growth, the United States can expect by the end of the century to use seven to eight times as much electricity as at present.

b. Non-Electrical Energy

Energy that has not been changed into electricity is used in many industrial processes such as the burning of coal and iron to make steel. Home and commercial installations use fossil fuels for space heating. Transportation accounts for one-fifth of the total United States fuel consumption in the form of oil and its by-products, mostly to power the internal combustion engine.

C. ENERGY EFFICIENCY

In estimating the impact of man's energy production on the environment, an important concept to keep in mind is energy efficiency. The greater the efficiency of an energy system, the less waste heat and pollution it produces. For example, the energy efficiency of an electric power plant is equal to the difference between the fuel energy input and the electric energy output. The average efficiency of both fossil fuel and nuclear power plants is approximately 33 per cent. In the transmission of electricity through wires and in the utilization of electricity by motors, air conditioners, stoves, heaters, light bulbs, and so forth, there are further losses of useful energy to heat.

Efficiency in energy production can be improved by technology. Efficiency in energy utilization from private homes to industrial complexes requires both new technology and new attitudes. A good example of the inefficient use of energy is the air conditioning of a restaurant or theater to the point where patrons must wear coats.

D. ENERGY AND THE AMERICAN FAMILY

How is the average American citizen concerned with a possible power shortage? What does he contribute to overall consumption? Forty per cent of the various petroleum products are used for heating private homes and running personal automobiles. Of the total electricity used, 10 per cent goes for heating and cooling in homes. In the state of Florida, for example, overall average family consumption more than doubled between 1960 and 1970 -- from 393 to 883 kilowatt-hours per month.[2] "All electric" homes are being built at an increasing rate although electric heaters and stoves offer a lower level of efficiency than gas and oil.

Industries vie with one another to create new electric items for the American family. The average family has around 30 electrical appliances in its home -- some as many as 50 -- and there are over 200 appliances on the market.

What would be the attitude of most Americans if they were asked to look about their homes and take note of what the loss or limitation of electric power would mean to the normal pattern of living? Among the items that could not be used are light fixtures, stoves, toasters, razors, refrigerators, air conditioners, can openers, lawn mowers, hedge trimmers, and on and on.

II. FOSSIL FUEL CONSUMPTION AND POLLUTION

A. FOSSIL FUEL CONSUMPTION

The United States population of 200 million people presently burns more energy than the 500 million people of Japan, Great Britain, Germany and the Soviet Union combined. In 1971 the country's 109 million cars used 90 billion gallons of gasoline, its 2,000 jetliners more than one billion gallons of jet fuel and its 3,480 power plants 1 billion barrels of oil, 4 billion cubic feet of natural gas and 300 million tons of coal. Between now and the year 2000 the United States will consume more energy than it has in its entire history. In the next twenty years alone the amount of energy used in the United States is expected to quadruple.

Over the past decade total energy consumption increased at an annual rate of about 2 per cent, while the population grew at a rate of about 1 per cent. The rate of United States per capita consumption each year is very close to the per capita consumption of the entire world, but the figure that is being compounded is about 6 times as large.[3] To put it more simply, the United States, with about 6 per cent of the world's population, presently accounts for about 33 per cent of the total world energy consumption, while the current demand for power is growing at a rate more than twice as fast as the population.

In 1970 almost all the energy consumed in the United States was supplied by fossil fuels: 43.5 per cent by oil, 32.5 per cent by natural gas, and 20 per cent by coal. Four per cent was supplied by hydrogeneration and less than 1 per cent by nuclear reactors. While the United States exports coal, a good deal of its liquid fuel supply is imported. Twenty-three per cent of the petroleum consumed in 1970 was from abroad. About 4 per cent of the domestic supply of natural gas was also imported. Data on total fuel consumption by economic sector and by source in the United States is given in the following tables:

FUEL CONSUMPTION IN THE UNITED STATES BY CONSUMING SECTOR

Consuming Sector	1947	1955	1965
Household and commercial	20.4%	21.6%	21.9%
Industrial	38.2%	34.7%	32.6%
Transportation	26.5%	24.6%	23.6%
Electrical Utilities	13.3%	16.7%	20.7%
Other	1.6%	2.4%	1.2%

SOURCE: U. S. Energy Policies - An Agenda for Research, Resources for the Future Staff Report, Johns Hopkins Press, Baltimore, Maryland 1968. Reprinted in Patient Earth, John Harte and Robert H. Socolow, Holt, Rinehart and Winston, Inc., New York, 1971, p. 288.

TOTAL U. S. CONSUMPTION OF ENERGY BY SOURCE

SELECTED YEARS, 1910 - 1969 (Trillion Btu)

Year	Coal	Natural gas	Petroleum	Hydro and Nuclear	Total
1910	12,714	540	1,007	539	14,800
1920	15,504	827	2,676	775	19,782
1930	13,639	1,969	5,898	785	22,288
1940	12,535	2,726	7,781	917	23,908
1950	12,913	6,150	13,489	1,601	34,153
1960	10,414	12,736	20,035	1,631	44,816
1969	13,458	21,037	28,374	2,776	65,645

SOURCE: Joel Darmstadter, "Trends and Patterns in U. S. and Worldwide Energy Consumption: A Background Review." Reprinted in To Live on Earth; Man and His Environment in Perspective, Resources for the Future Study, Sterling Brubaker, Johns Hopkins Press, Baltimore, 1972, p. 20.

If the American public has not been overly concerned about the manner and degree of its energy consumption habits, many predict that the summers of 1972 and 1973 will sharpen awareness. Complex environmental concerns have delayed the construction and operation of new fossil fuel and nuclear power plants. Federal court orders requiring full reviews of environmental effects in accordance with the 1969 National Environmental Policy Act must be met. Because of these delays Interior Secretary Rogers C. B. Morton has stated that "Serious power supply problems are anticipated in many areas, particularly in the Midwest around Chicago and in the Southeast, especially Florida and the Carolinas."

In a special in-house report prepared by the electrical industry it was recently stated that five of the nation's nine electrical regions would have fuel reserves below 10 per cent during the summer of 1972. The Federal Power Commission urges at least 20 per cent reserves. Such reserves are not surplus power, but a vital component of generating capability to cover failures, malfunctions and essential maintenance shut downs. It is estimated that a 20 per cent reserve level would result in only one failure in ten years, while a 10 per cent level would result in six occasions per year when load curtailment could be expected because of "multiplier factors." The report also stressed that power plant delays will hinder one region from coming to to the assistance of another.[4]

Thirty-five new fossil fuel and ten nuclear power production plants are involved. According to the report these plants are scheduled to provide 33 per cent of the nation's reserves in the summer of 1972, 30 per cent during the winter, and 35 per cent in the summer of 1973. The fossil fuel plants require water discharge permits from the Army Corps of Engineers, while the nuclear facilities also need operating licenses from the Atomic Energy Commission.

In one particular case, the construction of a power plant near Albany, New York, the United States court of appeals criticized the Federal Power Commission for not having issued appropriate environmental impact statements in accordance with the 1969 Act. When it was noted that critical power needs could be affected by power plant delays the court stated that "the spectre of a power crisis must not be used to create a blackout of environmental considerations in the agency review process."[5]

The Nixon Administration has introduced legislation in Congress that would permit operation of nuclear plants at 20 per cent capacity before reviews of their environmental impact are complete. At the same time, Russell E. Train, chairman of the President's Council on Environmental Quality has stressed that operation of nuclear plants at 20 per cent capacity would contribute little to reserves, but only allow them to perform necessary tests and eliminate delays before full output.[6]

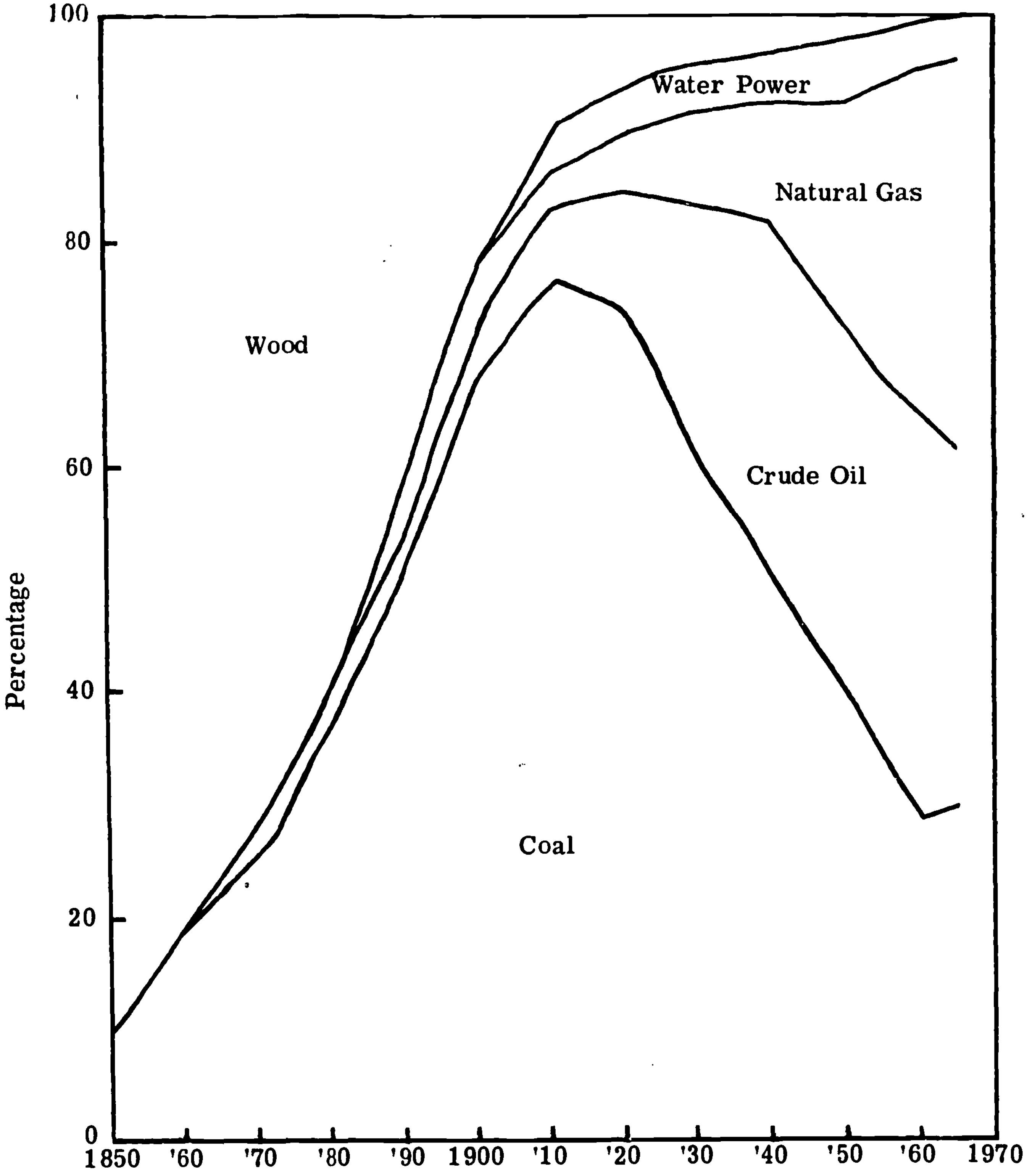
B. FOSSIL FUEL RESOURCES

The fuel resources of the United States have shifted steadily in the past half century. Fuel wood was the primary source of energy in 1850. By 1910 coal accounted for approximately 75 per cent of the total United States energy consumption. By 1950 petroleum replaced coal as the primary energy source, and has since maintained the lead. Since total consumption has risen, however, even coal consumption has been higher than for any year since 1948. Coal still dominates the electric power generating field and is important to industry, especially for the smelting of ferrous metals.

With the increasing scarcity of fossil fuel reserves nuclear reactors, as well as other radically different and potentially unlimited fuels, are being examined as alternatives. Some experts predict that by the turn of the century more than 50 per cent of the nation's energy needs will be met by nuclear power. At present there are twenty-three nuclear power plants in operational status, fifty-four being built, and fifty-seven planned. President Nixon has called for a concerted effort to have a demonstration "fast breeder" reactor by 1980, but it seems apparent that fossil fuels in various forms will be a primary source of power for several more decades. On the basis of historical evidence alone, about fifty years are required for the economy to shift substantially to a new fuel. Modern technology may be able to speed the process, but the environmental factors are complex and the cost of a rapid changeover both in terms of possible environmental damage and strict dollars and cents would be immense. The most pressing immediate problem is to find the necessary reserves of fossil fuels.

While domestic coal resources are in sufficient quantity to sustain their share of the economy, the reserves of liquid petroleum and natural gas are being depleted at a rapid rate. United States production of petroleum has exceeded usable additions to reserves every year since 1961. If the potential Alaskan North Slope reserves are excluded (transportation facilities have not been approved) the current oil supply in the lower forty-eight states is at the lowest point in twenty years. Natural gas reserves are at the lowest point since 1957.

The undiscovered, potentially recoverable crude oil in fields remaining to be found in the lower forty-eight states has been estimated by the National Petroleum Council to exceed 100 billion barrels. Currently, North



SOURCE: Brian Skinner, Earth Resources. Englewood Cliffs, N.J.: Prentice-Hall, 1969. Reprinted in Patient Earth, John Harte and Robert H. Socolow, Holt, Rinehart and Winston, Inc., New York, 1971, p. 287.

Slope reserves are estimated at more than 25 billion barrels, but it is believed that large quantities of oil remain to be discovered in Alaska. Large amounts of natural gas have also been discovered in Alaska, but S. David Freeman, one time energy adviser to Presidents Johnson and Nixon says, "It doesn't matter that we may have found 30 billion barrels of oil and more than 20 trillion cubic feet of gas in Alaska. Our rates of consumption are now so large that we can see the bottom of the barrel."[7]

Proved reserves of both crude oil and natural gas liquids stood at 37 billion barrels at the beginning of 1971. Measure these reserves against the 1970 consumption figure of 5.4 billion barrels of oil, with an expected doubling of this figure by 1985 should the annual increase in demand for oil continue at 5 per cent. In November 1971 the Oil and Gas Journal projected oil consumption at 230 billion barrels between 1970 and 1980, as against 225 billion barrels consumed since the Pennsylvania wildcat strikes in the nineteenth century.[8]

The shortage of gas reserves is partially the result of regulatory policies. The industry has complained that government clamps on economic incentives have cut growth rate. Nevertheless, the growth rate in the use of natural gas has consistently exceeded that of its energy producing competitors, especially during the past five years. This is primarily because natural gas is a cleaner burning fuel and does not present the pollution problems that must be confronted in the burning of petroleum and coal. But additions to natural gas reserves have continued to decline each year. In the past three years, the average volume of new reserves located annually has amounted to only one-half of the volume produced. It is estimated, however, that the undiscovered potential gas resources amount to approximately 1,200 trillion cubic feet, or four times the existing proved recoverable resources. Again, measure the reserves against the 1970 consumption rate of 21.7 trillion cubic feet, with an annual growth consumption rate of 6.2 per cent.

In December 1971, predicted shortages in natural gas supplies stimulated a public statement of concern from the White House. Fred Weinhold, energy specialist for the White House Office of Science and Technology said that "reserves and production of natural gas just haven't been increasing anywhere nearly as fast as demand." He pointed out that gas transmission companies in some southeastern cities told electric plants that used only natural gas to seek alternative sources of fuel because of the growing "demand - production crunch." According to Weinhold, some gas suppliers in the East and Midwest have been turning away new customers.[9] The winter of 1971 did not see a widespread lack of availability of natural gas, but the situation serves to highlight the need for alternative sources of power.

Even the most conservative estimates of available fossil fuel supplies recognize that the processes of removal, refinement, and utilization will become increasingly more expensive. There is, however, a current debate over how much the consumer should be asked to pay. In November 1971 the Oil and Gas Journal stated that the United States is not running out of energy, but warned that it is running out of cheap energy. The industry contends that higher prices would intensify prospecting and presumably lead to the discovery of sufficient new deposits. It also wants increased freedom to do offshore drilling and is pressing for the Alaskan pipeline to bring North Slope oil to the rest of the United States. The primary reason given for impending sharp price increases is the new ingredients that must be refined. According to the Journal:

> Additional domestic gas and oil deposits will be brought into production, of course, But the finding will be more difficult and costly. We already know the extent of many other hydrocarbon resources: coal, heavy oil, black oil, tar sands, and shale oil. These cannot, however, be extracted at the turn of a valve. They now cost more to recover than flush oil and gas production. And they will cost successively more than the convenience fuels to which Americans have become accustomed.[10]

If enough new deposits cannot be discovered economically, or if they do not actually exist in sufficient quantity, there will be increasing dependence on imported fuel oil which will raise the cost of overall energy production. Some experts suggest that by the 1980's almost 50 per cent of the U. S. petroleum supply will be imported at a cost of between $12 and $15 billion a year.

Utilities argue that they need more money to meet higher construction costs and the price of anti-pollution equipment. Since the beginning of the 1970 decade, utility costs have been advancing at close to double the rate of the overall cost-of-living index. In the twelve months ending in September 1971, prices of both gas and electricity rose 7.4 per cent. The overall consumer price index rose 4.2 per cent during the same period. In 1969 it cost $168 to heat a six room house in Chicago with gas, but by 1971 it cost $186. In Denver the price rose from $103 to $112 between 1969 and 1971.[11] At the time of this writing a record number of rate-increase applications are pending before state and other governmental regulatory agencies. More than sixty utilities are seeking increases that, if approved, will raise the overall cost of electricity more than $1 billion a year. At the same time, after-tax profits of the country's 100 largest private power companies totaled a record $3.3 billion in 1970, up $250 million from 1969.[12]

There are some who do not agree with the utility industry's rationale for requesting rate increases. They claim that companies are enriching themselves at the expense of their customers. For example, United States Senator Metcalf claims that electric utilities spent seven times more on advertising and sales promotion in 1970 than on research and development. "If the utilities quit overpromoting their scarce product," he maintains, "they would not need as much additional plant capacity, and research and development could lead to more pollution free production of power."[13] The power companies have argued, on the other hand, that advertising promotes increased efficiency in power production because plants generate less waste heat as they reach peak generating capacity. Senator Metcalf is presently sponsoring legislation that would provide funds for hiring lawyers to represent the public before regulatory commissions and courts. He feels that all too often highly paid economists, engineers and accountants representing the utilities overwhelm state regulatory commissions.

However this debate is resolved, one thing is certain, fossil fuel energy is cheaper than it would be if its price reflected all the environmental effects of combustion, mine wastes, destruction of the landscape by strip mining, the effects of air pollutants on health, and so on. If public policy is beginning to include these costs more completely, it will certainly do much to encourage more rational and efficient use of fuel.

C. ENERGY EFFICIENCY

Conversion efficiency is one key to a cleaner environment. The higher the efficiency of an energy system, the more usable power is produced per unit of fuel, and the less pollution and waste. Some experts have suggested that the waste heat produced from power generation today would be enough to heat every home in the United States.

There has been a great deal of attention in the energy industry to efficient energy production, but society has not paid the same attention to achieving efficiency in energy utilization. This is partly because energy has been relatively cheap in the past, making the cost of its utilization only a fraction of the total cost of an industrial or household process. Many industries continue to receive energy supplies at bulk rates which results in minimal concern for its efficient use. But as the impact of energy consumption on the environment becomes a more central concern and as brownouts occur with greater frequency efficiency in both the production and utilization of energy is becoming a critical subject. Three examples will be used to illustrate the point: home furnaces, the internal combustion engine, and steam-electric turbines.

1. Home Furnaces

At the turn of the century more than half of all the fuel consumed in the United States was used for space heating. The average efficiency of a wood or coal home furnace was about 20 per cent. Today, fossil fuel combustion in a well designed home furnace is between 50 and 55 per cent efficient. Fossil fuel consumption for space heating has, however, declined significantly. It now accounts for less than one-third of total U. S. fuel consumption. This is because electrical heating systems have captured more and more of the market. But the increased use of electricity for home heating represents an inefficient use of fuel, since a good oil or gas burning home furnace is about twice as efficient as the average electric-generating station.[14]

2. Internal Combustion Engine

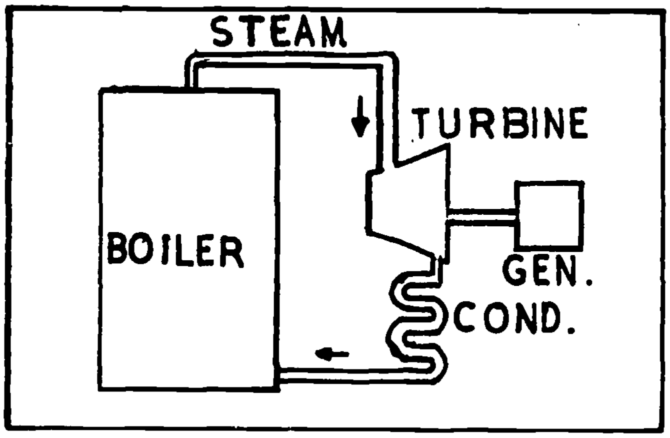
The nation's more than 100 million motor vehicles account for more than 16 per cent of our fossil fuel consumption. The efficiency of the internal combustion engine averages about 25 per cent. (All U.S. transportation absorbs about 25 per cent of the nation's energy needs.) While the average automobile engine efficiency has increased about 10 per cent in the last 50 years, it is believed that the basic efficiency of the piston engine cannot be improved much further.

3. Steam - Electric Turbines

Since 1900 the electric power industry has shown dramatic gains in fuel conversion efficiency. At the turn of the century less than 5 per cent of the energy in the fuel was converted to electricity. Today the average efficiency is about 33 per cent. The rise in conversion efficiency has been achieved largely by increasing the temperature of the steam entering the turbines that turn the electric generators, by building larger generating units, and by running these units at full capacity.

Currently, the electrical energy provided by steam power plants that burn fossil fuels account for approximately 75 per cent of the nation's power supply. The burning of these fuels to create steam contributes to high atmospheric concentrations of sulfur dioxide, particulates and oxides of nitrogen.

A three-stage mechanical process is employed to generate this power. Water is heated in a furnace boiler until it becomes high pressure steam. This steam is then employed to spin a huge turbine. In the last stage, the turbine drives a big rotary motor-generator that whirls a copper wire armature through a magnetic field to produce electrical current.



FOSSIL-FUEL STEAM POWER PLANT

To a certain extent, energy utilization can be made more efficient by technical innovations. For example, one author discussed the possibility of slowing a subway by transferring much of its kenetic energy into the rotational energy of a flywheel, instead of into heat and noise, and then to start the subway up again by transferring the kinetic energy back from the flywheel to the train.

How efficiently energy is used may also be affected by regulating the cost of electric power. Inverted price schedules may encourage both industry and the consumer to support research directed toward achieving greater efficiency in energy production and search for new attitudes to improve its utilization. There are possibilities for utilizing waste heat in space heating, sewage treatment, and agriculture, but research will be required to establish them.

D. FOSSIL FUEL POLLUTION

How much has already been spent, and how much it will cost in the future to abate pollution caused by the production of energy is still largely uncertain. There is currently no objective methodology for figuring the cost of pollution in terms of environmental degradation. Although one estimate of the total cost of meeting energy needs alone by the end of the century is $500 billion, about all that can be said with any assurance is that cost analysis of both production and pollution abatement aspects of the problem is a controversial issue. Industrial spokesmen recognize that new technology is needed, while conservationists are quick to demand why such technology has not been developed and what is being done to develop it.

At present, the electric utility industry spends less than one quarter of 1 per cent of its operating revenue on research and development. Government support in 1970 amounted to about $350 million, of which 85 per cent went directly to nuclear energy research. J. Harris Ward, chairman of Chicago's Commonwealth Edison Company, says that $165 million has already been spent and that the company expects to spend $400 million over the next five years for air and water quality control systems at generating sites. This figure amounts to 13 per cent of the company's total construction budget. At the same time, according to the Florida Petroleum Council, the entire U. S. petroleum industry spent only $36.2 million on research in 1970. Fortune magazine reports that Humble Oil Contemplates spending $60 million to change its name brand to Exxon.[15] In the face of critical energy and environmental needs, environmentalists point out, the money could be more wisely spent.

Environmental groups are beginning to ask critical questions. An awakened public is beginning to wonder what the budgetary dedication to research has been and how it compares with allocations for advertising, public relations, lobbying, and similar activities. The American public may soon be confronted with brownout and possibly blackout situations, along with increasing utility rates that will force a resolution of the question as to who will pay the costs for the necessary research and development and how much delay can be afforded. There seems little doubt that attitudes and priorities will have to be thoroughly examined. At the present time, for example, the tremendous amount of energy that is consumed in industrial production, travel, heat, air conditioning, washing machines, refrigerators, etc., is done without much consideration for the energy requirements of extensive recycling. Some of the current fossil fuel pollution problems that must be considered are discussed below.

1. Thermal Pollution

Steam-electric generating plants require huge amounts of water to cool the plant and to generate steam. Unless there is a closed-circuit flow heated water is discharged back into the environment. Excess heat from power plants that do not utilize cooling ponds or cooling towers raises water temperature around the discharge ten to thirty degrees causing harmful biological effects.

The seriousness of solving the problem of thermal pollution is illustrated by one author who states that "by the year 2000. . . . the total cooling water requirements of the United States steam-electric industry are expected to approximate one-third of the country's entire yearly supply of runoff water." This conclusion is based on the following assumptions that could be modified by technology:

(a) The annual 7 per cent growth rate for electricity will continue.

(b) Modern electrical power plants will continue to operate at maximum of 40 per cent efficiency.

(c) Water that cools power plants will be heated 20° F on the average.

(d) Half of the heat will be reflected to runoff water, the other half being rejected to the atmosphere through cooling ponds and cooling towers and to the oceans.

(e) Runoff water will never be used twice on its way to the sea.

(f) The United States runoff, which is now 30 per cent of rainfall (average rainfall is 30 inches), will not be modified.[16]

2. Natural Gas

The principal market for natural gas is households and commercial installations that use it for space heating. Industry also uses it to process heat. Natural gas burns with few residuals in most cases, but sufficient quantities to reduce overall pollution are not available. It still produces about 25 per cent of the United States electrical power, but current estimates say the figure will be below 6 per cent of the total by the end of the century. Industry spokesmen have indicated that synthetic gas manufactured from coal and oil shale "could provide substantial energy supplies," but contributions of systhetics to the total energy supply is not likely to be significant until the 1980's because of technological and economic problems.[17]

3. Coal and Oil

Coal is in plentiful supply, but most of it contains high concentrations of pollutants, particularly sulfur. Low sulfur coal is available but it is in short supply and therefore relatively expensive. Petroleum shares some of the disadvantages of coal, creating environmental burdens in production, transportation and use, although it is somewhat more manageable in burning. As in the case of coal, there are both high and low sulfur varieties. The supply of low sulfur oil is expensive and scarce, most of it being imported. There are, however, compensations such as lower maintenance cost and, of course, aesthetic considerations not traditionally accounted for in dollars and cents.

Reliance upon fossil fuels inevitably results in more carbon dioxide, no matter how efficiently they are burned. The concentration of carbon dioxide in the atmosphere is on the increase (each year the burning of fossil fuels produces an amount of carbon dioxide equal to about 0.5 per cent of the existing carbon dioxide reservoir in the atmosphere) and will ultimately have an effect on the heat balance of the earth. Mechanisms for the removal of carbon dioxide are only partly understood, and only limited research has been proposed to solve the problem.

Electric power generation has been the prime source of sulfur pollution. Data on 1966 emissions are given in the following chart:

Source	Sulfur Dioxide	Particulates	Oxides of Nitrogen	Hydrocarbons	Carbon Monoxide
Automobiles	1	1	6	12	66
Major industries[a]	9	6	2	4	2
Electric power generation	12	3	3	1	1
Space heating (indoor heating)	3	1	1	1	1
Refuse disposal	1	1	1	1	1
Total	26	12	13	19	72

SOURCE: "The Sources of Air Pollution and their Control," Public Health Service Publication No. 1548, Washington, D.C., 1966. Reprinted in Patient Earth, John Harte and Robert H. Socolow, Holt, Rinehart and Winston, Inc., New York, 1971, p. 48.

[a] Includes only the six major industrial polluters.

In terms of percentages 1968 data indicate that both coal and oil burned in electric plants and in other stationary sources, such as space heating and industrial activity, contributed major fractions of all sulfur dioxides (74 per cent), nitrogen oxides (49 per cent), and particulates (31 per cent) emitted in the United States.

There is no economical technology available for reducing the sulfur content of fuels before they are burned, but some cities, such as New York have reduced sulfur dioxide emissions by converting to low sulfur fuels. This is, however, only a limited solution since supplies of low sulfur fuel are diminishing.

One other method that has been employed to combat sulfur dioxide pollution is interruptable gas service. Some electric companies are equipped to use this method. It is also used in some major metropolitan areas in the case of space heating. The strategy is to install equipment which burns natural gas unless the outside temperature falls below a preset value, at which point a low sulfur oil or coal can be substituted. Again, however, this is a limited solution primarily because of the increasing lack of availability of natural gas and low sulfur coal and oil.

Transportation accounts for about 25 per cent of all the energy consumed in the United States, almost all of which is in the form of petroleum products. In 1969 the movement of goods and people around the nation accounted for well over 300 million tons of fuel and additives. This total includes 180 thousand tons of lead. Most of this total was consumed by private automobiles. More than 80 per cent of all workers travel to work by car, while most of the rest use buses. Cars and buses account for the vast majority of intercity passenger miles, although the airlines are beginning to account for approximately 10 per cent of the total. Most freight still moves by rail and barge, but trucks monopolize the local distribution of goods. Fuel consumed by ships is away from harbors and is not of immediate environmental concern. If present automobile consumption trends continue, there may be 200 to 250 million cars on the road by the end of the century. Many critics of the automobile argue that even with emission control technology the number of cars will make it impossible to reduce pollutants below tolerable levels. At present the automobile is the primary contributor to over 60 per cent of the carbon monoxide, over 50 per cent of the hydrocarbons, and about 40 per cent of the nitrogen oxides emitted into the atmosphere. There seems little doubt that if the United States wishes to economize on energy consumption, more rational systems of transportation must be developed.[18]

If the United States wishes to control pollution and make sure of having really long-term energy supplies, radically new energy production technologies must be developed. At present, the most promising alternative is advanced nuclear technology.

III. SOLUTION

A. NUCLEAR ENERGY

1. Fission Reactor

All of the commercial nuclear reactors now in operation are controlled fission reactors; that is, under controlled conditions a chain reaction is sustained where nuclei of uranium 235 atoms are split by neutrons, thus releasing more neutrons to continue the process. Heat is generated as a result. The amount of energy released per atom in a fission reaction exceeds the amount of combustion reactions by factors of several millions. For example, the fission of 1 pound of nuclear fuel liberates an amount of energy equivalent to the combustion of 3 million pounds of coal. The fission reaction also generates much higher temperatures and takes place in a much shorter time.

Aside from the fission reaction, operational nuclear power plants are similar to conventional plants. Both use steam to drive a turbine generator that produces electricity. Whereas conventional power plants burn coal, oil or gas, nuclear plants use the heat created by the fission reaction to create steam.

The efficiency of controlled fission nuclear power plants is about the same as conventional plants and they are more expensive to build, but the absence of air pollution and the increased production capabilities of nuclear fuel make them attractive. There is, however, widespread debate on the possibility of radiation leakage and a major nuclear accident, a subject that undoubtedly needs more research. Dr. Hannes Alfren, 1970 Nobel Laureate in physics, recently stated in a memorandum to Senator Mike Gravel that "the dangers associated with fission energy have not received necessary attention." There is also the problem of thermal pollution. Most nuclear plants are not equipped with proper equipment to keep from dumping heated water back into the environment. The operation and construction of numerous plants has been stopped by environmental groups for this reason. Technology is available to overcome this problem.

If the burden of generating power is shifted from fossil fuels to uranium, as presently used, accelerating demands could deplete resources by the end of the century. For this reason the Atomic Energy Commission is doing research on fast breeder fission reactors.

2. Fast Breeder Reactor

President Nixon has called for stepped up federal support for development of the breeder reactor, including an increased share in the government's contribution to construction of a demonstration plant by 1980. Current estimates of the cost of the plant are in the range of $600 million, with the government presently agreed to pay $130 million.

The breeder reactor gets its name from the fact that it actually creates more fuel than it uses. In current fission reactions uranium 235 fissions when its nucleus absorbs a neutron. The fission reaction releases free neutrons that initiate other fissions, but some of the neutrons are absorbed in the structural material, control elements, and coolant in the reactor. In the breeder reactor, neutrons not needed to sustain the fission reaction are used to convert certain "fertile" materials into fissionable material. One such fertile material is uranium 238. Of the uranium that is mined, about 1 per cent is uranium 235. Almost all the rest is non-fissionable uranium 238. When uranium 238 nuclei absorb neutrons, they are converted to fissionable plutonium 239. With a breeder reactor it may be possible to use as much as 50 per cent of the energy in uranium.

Plutonium is an extremely dangerous potential pollutant. It is an insoluble element with a half life of 24 thousand years that is virtually non-existent in the earth's crust. It is known to be carcenogenic in animals in microgram quantities. There is strong controversy over whether or not sufficient safeguards can be established before commercial operation begins. What to do with the radioactive waste produced by a full scale program is the most critical question. Many scientists contend that, at present, it is not evident that the waste problem can be solved in a satisfactory way.

Enthusiasm for the breeder reactor on the part of utilities has been minimal of late. This is partly because of preoccupation with getting current fission reactors ready to meet increased utility loads. Problems with licensing, construction, environment and safety have proved greater than envisioned only a few years ago. It seems likely that similar problems will be confronted with the breeder reactor.

3. Fusion Reactor

In a fusion reactor atoms are joined together rather than split apart. Fusion is the energy of the stars. When hydrogen atoms join, as they do under conditions of tremendous heat, they fuse to form an atom of helium. Energy is given off in the process. In the sun, for example, approximately 4 billion hydrogen atoms are fused every minute. Although some are optimistic that the technology for constructing a fusion reactor can be developed before 1990, others put it as far away as the middle of the twenty-first century.

The problem is that to get energy from the fusion process it is necessary to create heat of around 180 million degrees Fahrenheit, a temperature that melts all known materials. Uncontrolled fusion reactions have been triggered in bombs by using the heat generated by an initial fission explosion. Under controlled conditions it may be possible to obtain the necessary heat with electric currents that vibrate hydrogen plasma (a gas at high temperatures is called a plasma, the fourth state of matter), with microwaves, strong magnetic fields or laser beams. Since there is no known substance that can contain a fission reaction, physicists believe that a force can be used instead. For example, superconducting magnets can be constructed to create magnetic fields that will contain or "bottle" the reaction.

On earth hydrogen is in abundant supply in the oceans. Scientists presently consider using deuterium or heavy water in the fusion process. One atom of deuterium occurs per 5 thousand atoms of ordinary light hydrogen in water. Consequently, fusion energy exists in virtually unlimited supply. It would be pollution free and vastly superior to fission because only tiny amounts of fuel are required to produce tremendous quantities of energy, as opposed to large amounts of toxic fuel and waste, particularly in the fast breeder fission process.

Even by today's methods it costs only about 4 cents to extract the deuterium in a gallon of water, an amount that contains the same energy as 300 gallons of gasoline. One estimate says that 30 cubic kilometers of seawater would contain deuterium energy equivalent to the current inventory of fossil fuels on earth.

B. SOLAR ENERGY

Enough pollution free solar energy falls on the U. S. every twenty minutes to fill the nation's entire power needs for a year, but at the present time the use of the sun's rays to generate usable energy is only in the proposal stage. Most experts agree that it will not be economically feasible to have such a system in operation before 1990. Several U. S. corporations are, however, currently trying to persuade the National Aeronautics and Space Administration that funding a research and development effort at this time would not be premature. Dr. Peter E. Glaser, vice president of one of these corporations, has developed one of the most imaginative ideas for harnassing the sun's energy.

Dr. Glaser has proposed development of a large space platform, composed of a mosaic of solar cells that would convert sunlight to electric power. He maintains that all of the working elements for such a system are currently available or can soon be developed. According to Glaser's calculations a five mile square of solar cells in stationary orbit about 22,000 miles above the equator could transmit enough power to supply New York City. As long as the power station is in space efficiency is not limited by cloud cover and darkness.

Cost estimates of such a system are currently unrealistic, but Dr. Glaser believes that the initial cost of energy would be about twice as much as conventional steam power. His estimate is based on NASA's launching a space station and space shuttle service, which is expected to reduce the cost of lifting bodies into orbit below $100 per pound.[19]

C. GEOTHERMAL ENERGY

Some expect that a future source of power will be the interior heat of the earth. This heat is available in enormous underground pools of hot water and steam that could be used for the generation of electricity in place of the combustion of fossil fuels. Advocates of geothermal energy indicate that California is one state with large quantities of this resource. Richard G. Bowen, geologist with the Oregon Department of Geology and Mineral Industries, has estimated the construction cost of a geothermal plant at about two-thirds that of a fossil fuel plant and one-half that of a nuclear plant, but cost estimates are still highly speculative.

D. SUPERCONDUCTIVITY

Superconductivity refers to certain metals that, if cooled to temperature near absolute zero (minus 460 degrees Fahrenheit) suddenly lose all resistance to electric current and become perfect conductors. They carry current without heat or energy loss of any kind. Ordinary copper conductors, operating at normal temperatures, have an average efficiency near 80 per cent.

Superconducting materials can be used in electromagnets, generators, motors, transformers, circuits, and transmission lines. The largest superconducting electromagnet (electromagnets are basic to all power production) is at the Argonne National Laboratory near Chicago. It is seventeen feet in diameter. A conventional magnet of the same capacity would have required 10 megawatts of power, plus thousands of gallons of cooling water per day. The Argonne magnet requires only 300 kilowatts, most of it to run the helium refrigerator that keeps the magnet cool. The saving in power cost alone is estimated at between $350 thousand and $400 thousand a year.[20]

Union Carbide Corporation has done most of the research on superconducting transmission lines. The original problem was that super conducting lines could carry only DC current, and there is only one major DC transmission line in the United States. But in 1970 Union Carbide successfully demonstrated a super cooled AC cable. It was estimated that one full scale, 345 kilovolt superconducting line, twenty inches in diameter, could carry more power than is now used in all of New York City. Twenty-two ten inch conventional cables would be required to carry the same load.

The cost of converting to superconducting metals, particularly in the case of transmission lines, is difficult to determine. At present, the price of the necessary metals cannot compete with conventional copper. There is also the added cost of refrigeration. What is more, superconducting lines must run underground for the most efficient operation. If the cost is not prohibitive the countryside would certainly gain a good deal in terms of aesthetic value. For example, a proposed 120-mile-long, 345 thousand volt transmission line for New York State would take up about five square miles. At the same time, one estimate for putting all conventional transmission lines underground is in the area of $350 billion, while other estimates have been much higher. Some experts contend that this cost could be greatly reduced by using superconducting cables. Research is needed.[21]

E. MAGNETOHYDRODYNAMICS

Magnetohydrodynamics (MHD) became feasible with the intensive development of gas dynamics and high temperature materials in rocket and aerospace technology. MHD is capable of reducing the three stages of the conventional steam generating process to one continuous process by utilizing hot gases obtained from the burning of coal or oil at extremely high temperatures.

A high-velocity stream of hot (4 thousand to 5 thousand degrees Fahrenheit), conductive gases is shot through a long tube surrounded by electromagnets and current is drawn off by electrodes along the length of the tube. One test plant developed by the MHD pioneering firm of Avco, with the Edison Electric Institute and several New England utilities, demonstrated efficiency as high as 60 per cent. Also, because of its high operating temperature, MHD promotes more complete combustion of the hydrocarbon fuels it burns and promises about one-third less pollution than conventional plants of the same capacity.

Proposals for the development of prototype MHD plants include recycling systems to recover particulate, nitrogen oxide, and sulfur pollutants as well as hot exhaust gases in order to obtain the ultimate amount of power. Although research has been limited in the United States (West Germany, Japan and the Soviet Union have been doing intensive research) the office of Science and Technology has estimated that MHD could save more than $11 billion between 1985 and the turn of the century at present coal prices.[22]

F. WASTE RECYCLING

Numerous industries in the United States have begun to find it profitable to recycle waste products and to generate power in the process. For example, Combustion Equipment Associates, Inc., has discovered a way to recycle waste and generate power for plants involved in the manufacture of plastics. The process will be tested at the Spaulding Fibre Company's plant in Tonawanda, New York, late in 1972.

The standard solution to the pollution problems at the Spaulding plant would have been to install electrostatic precipitators on the smoke stacks and switch from coal to low sulfur or gas fuels for the seven boilers that provide 125 thousand pounds of steam every hour. But the company would still be left with the problem of incinerating solid wastes and trying to recover still usable chemicals from liquid wastes. Since this would have been costly to Spaulding, Combustion Equipment Associates decided to install a closed loop incineration system that burns all industrial waste and uses the resulting heat to generate steam for powering the plant's manufacturing operations. In working out the new waste recycling system Combustion Equipment Associates took into consideration that Spaulding was paying $10 to $15 a ton to dispose of solid wastes that had a fuel value of 8 thousand to 10 thousand Btu's. The process will involve the use of 8 thousand gallons a day of waste liquids from paper and resin operations in the plant and forty tons a day of solid scrap trimmed from laminates. The reclaimed heat will enable Spaulding to close down the seven boilers that normally consume 110 tons of coal a week.

Combustion Equipment Associates has contracted with Spaulding to operate the system for a fifteen year period and estimates that it will receive minimum revenues of $1 million a year as a result. "This has opened up an entire new business for us," said Robert M. Beningson, president of Combustion Equipment, "We have nine additional projects in the proposal stage right now."[23]

IV. CONCLUSION

One author had the following to say about United States energy problems:

> The problem of pressing new and beneficial technologies in a highly developed nation such as the U. S. is becoming more obdurate than any of the problems facing underveloped countries. The immense investment in the internal combustion engine precludes any intensive development of the fuel cell or other electrical alternatives for a truly nonpolluting automobile. The dead capital weight of obsolete railroad and mass-transit systems, sucked dry, blocks the concerted development of advanced high-speed electric ground transportation systems, already appearing elsewhere in the world. And the U. S. electricial industry, which might be contributing to solutions in these areas, is showing some of the same capital inertia. The country that built the world's first central power station is now in danger of losing its leadership in the new level of technologies the times require. Snug in the complacency that U. S. technology leads all the world, the country has not kept its eye on the major index of modern industrial civilization-energy.[24]

Another put it this way:

> The assertion that pollution control can be had at tolerable costs assumes that we will not be dogmatic or hysterical about the requirements that we place on industries or public agencies. Crash programs of doubtful necessity can be very costly. On the other hand, if we press ahead with a clear sense of direction and urgency while still allowing reasonable time to gestate necessary technical measures and to plan investments on an orderly basis, costs can be far lower.[25]

How would you state the problem?

FOOTNOTES

1. John Harte and Robert H. Socolow, Patient Earth (New York: Holt, Rinehart and Winston, Inc., 1971), p. 284.

2. Orlando Sentinel, November 29, 1971.

3. Harte and Socolow, op. cit., p. 285.

4. Melbourne Times, March 29, 1972

5. Ibid.

6. New York Times, January 31, 1972.

7. Orlando Sentinel, November 30, 1971.

8. Miami Herald, April 30, 1972.

9. Miami Herald, December 1, 1971.

10. Orlando Sentinel, November 30, 1971.

11. National Observer, January 29, 1972.

12. Ibid.

13. Ibid.

14. Claude M. Summers, "The Conversion of Energy," Scientific American, September 1971, p. 149.

15. Orlando Sentinel, November 30, 1971

16. Harte and Socolow, op. cit., p. 264.

17. Orlando Sentinel, November 30, 1971.

18. Sterling Brubaker, To Live On Earth: Man and His Environment in Perspective (Baltimore: Johns Hopkins Press, 1972), p. 25.

19. Lawrence Lessing, "New Ways to More Power with Less Pollution", Fortune, November 1970, p. 132.

20. Ibid.

21. Reed Millard and the editors of Science Book Associates, *How Will We Meet the Energy Crisis: Power for Tomorrow's World*, (New York: Julian Messner, 1971), p. 77.

22. Lessing, *op. cit.*

23. *New York Times*, March 5, 1972.

24. Lessing, *op. cit.*, p. 133

25. Brubaker, *op. cit.*, p. 156

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