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SECRETARY'S ANNUAL REPORT TO CONGRESS

January 1981

Volume I Posture Statement, Outlook and Program Review

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U.S. Department of Energy

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Volume I

Posture Statement, Outlook and Program Review

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Preface

This is the third *Annual Report* of the U.S. Department of Energy and covers activities of all elements of the Department except the independent Federal Energy Regulatory Commission, which issues its own annual report. This *Annual Report* consists of three volumes: Volume I "Posture Statement, Program Review and Outlook," Volume II "Budget Highlights—1982," and Volume III "Project Summaries."

This report is supplemented by three annexes listed on page XIV. All years are fiscal years unless otherwise noted.

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- 2.⁴ *Third Annual Report to Congress on the Automotive Technology Development Program* (in preparation by the Office of Transportation Programs, Office of Conservation and Solar Energy, U.S. Department of Energy).
- 3.¹ *Observations and Recommendations on the Future of the Energy Extension Service Program: Third Report by the National Energy Extension Service Advisory Board* (in preparation by the Office of State and Local Programs, Office of Conservation and Solar Energy, U.S. Department of Energy).

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Chapter 1

Posture Statement

Introduction

The United States has an energy problem. The 1973 oil embargo brought home to the American people the increasing scarcity and expense of conventional forms of energy and clearly underscored the reality that domestic sources of oil and natural gas could not supply all our Nation's needs for these fuels. It made clear that the economies of the United States and of our allies depended on a stream of imported oil, a stream that we could not make entirely secure. It also showed that policies to reverse these conditions did not exist.

Today, 7 years after the oil embargo, we have a comprehensive energy policy. This policy, laboriously worked out by several Administrations and Congresses, has begun to show results: it is decreasing our reliance on foreign oil, increasing the development of domestic energy sources, and improving the efficiency with which we use energy. While there has been no "solution" to the energy crisis, the Government, the marketplace, and individual Americans have recognized the problem and have taken many different steps to help ensure that the Nation will have secure sources of energy to meet the demands of a growing economy.

The Department of Energy was created in October 1977 from parts of eight Federal agencies. Under both former Secretary James R. Schlesinger and Secretary Charles W. Duncan, Jr., the Department of Energy has played a leading role in the formulation and implementation of energy policy. This report describes the Depart-

ment's activities during 1980, its programs for 1981, and its plans for 1982.

This chapter, the Posture Statement, gives an overview of the Department's policies, programs, and strategies. It first describes our national energy policy and its effects. Next, the Statement sets out the current state of energy supply and demand in the United States and around the world. It then describes our present assessment of future energy availability. Finally, it outlines the Department's strategy and programs for 1982. The remaining chapters of this *Annual Report* detail all of the Department's major programs.

Development and Implementation of a National Energy Policy

The Arab oil embargo of 1973 was our first obvious warning that the days of cheap and readily available energy were over. The gasoline lines it caused provided Americans with their first experience with the effects of an energy crisis. The major actions taken to combat the energy problem between the time of the embargo and before 1977 were the imposition of price and allocation controls on crude oil and refined products. These were intended to soften the effect of rising energy prices on the economy and to preserve the competitive ability of the independent sector of the oil industry. Legislation was also passed to provide some assistance for voluntary action toward energy conservation, gasoline mileage standards for new automobiles, conversion of certain oil-fired boilers to coal, and the creation

of the Federal Energy Administration and the Energy Research and Development Administration.

While price controls on oil and gas may have temporarily had a favorable influence on the rate of inflation, they tended to discourage full development of our oil and gas resources and refining facilities. They also encouraged the wasteful use of energy. Total energy consumption in the United States had increased from 36.5 million barrels per day of oil equivalent (MMBDOE) in 1973 to 37.5 MMBDOE 4 years later.¹ More significantly, consumption of petroleum rose from 17.3 million barrels per day in 1973 to 18.4 in 1977. At the same time, however, domestic production of petroleum fell from 10.9 million barrels per day to 9.9 million barrels per day, in spite of the addition of 0.5 million barrels per day from the North Slope of Alaska during the last half of 1977. As a result, imports of oil to the United States rose to a record level of 8.6 million barrels per day in 1977, a 42-percent increase, or more than 2.5 million barrels per day, from the year of the oil embargo. At 1977 prices, the Nation experienced an additional daily cost of \$37 million for foreign oil.

Since 1977, national energy policy has taken a substantially different direction in the form of presidential directives and several significant legislative enactments that had bipartisan support in Congress. That policy begins by recognizing that the energy problem is real. While energy supplies are not about to disappear, they are becoming more expensive and less secure. Any attempt to shield the economy from these changes will only lead to an eventual catastrophe; instead, the country, led by policy reforms undertaken by the Federal Government, must adjust to the changes in available energy sources in a productive way.

The national energy policy has five main parts. First, replacement cost pricing of energy is the keystone of this policy. The phased decontrol of oil (by executive action under the authority of the Energy Policy and Conservation Act of 1975) and a significant step in the direction of natural gas decontrol (by the Natural Gas Policy Act of 1978) are critical components of our policy as they both reduce energy demand and increase the incentives for domestic producers to find more energy.

Second, current policy is directed toward more use of domestic sources of energy, including energy conservation, which in the short term may be viewed as one of our best alternative sources of domestic energy. Conservation does not necessarily require sacrifice; it means making better use of scarce energy resources. Coal and other available

alternatives must replace costly oil. The Powerplant and Industrial Fuel Use Act gave the Department the ability to order and to encourage conversions of oil-fired boilers to alternative fuel sources. We must get more oil and gas from new and existing fields in the lower-48 states, in Alaska, and on the outer continental shelf. Regulatory changes, including most notably the phased decontrol of crude oil, will help achieve these goals. Tax credits, provided by the Energy Tax Act and the Energy Security Act, among other statutes, are encouraging increased production and more prudent use of energy resources. Consumer information about energy costs and energy alternatives, provided through literature and advertising or through residential energy audits conducted under the Residential Conservation Service, leads to energy conservation. Similarly, information and assistance provided to state public utility commissions, authorized by the Public Utility Regulatory Policies Act, promotes the efficient implementation of rate structures that encourage energy conservation. Energy performance standards for new buildings and for appliances will also help us reach our conservation goals.

Third, national energy policy encourages the discovery and development of new sources of energy. This includes not only research and development of new energy resources but also helps more advanced concepts enter the commercial market. The Federal Government's energy research and development budget has risen more than 100 percent since 1978. For example, funds for fusion energy, a long-term alternative of great promise, have increased from \$325 million in 1978 to a planned investment of \$506 million for 1982. Alternatives of more immediate value, such as solar thermal powerplants, coal gasification, and coal liquefaction, have been encouraged through Federal participation in demonstration plants. Still more immediate alternatives, such as alcohol fuels, solar thermal heating, and oil shale, have been encouraged through tax incentives and through direct Government assistance in the form of loan guarantees, price supports, purchase commitments, and grants. Congress appropriated \$5.5 billion for the Department to use to encourage the near-term production from alternative energy sources. More important, the Energy Security Act was enacted, creating a Synthetic Fuels Corporation with the authority to extend \$20 billion in Federal financial incentives, which will help to establish a synthetic fuels industry necessary to lessen our dependence on foreign oil.

Fourth, the Government has taken steps to prepare the Nation for energy emergencies. Today, as in 1973 and in 1979, the United States is vulnerable to major economic disruptions from any significant interruption in the flow of oil. We are better prepared today, however, to deal with such supply interruptions. Through the International Energy Agency, progress has been made in implementing a

¹Large amounts of energy are often expressed in terms of quads. One quad is one quadrillion British thermal units (Btu's). One Btu is the energy it takes to heat 1 pound of water from 39° to 40°F. Because these terms are little known and somewhat difficult to grasp, we will use a unit measure that is equivalent to 1 million barrels of oil per day for a year (1 MMBDOE). This unit is roughly equal to 2 quads.

structure for sharing serious shortages with our major industrial allies throughout the world. Through the Emergency Energy Conservation Act, the Department has developed a standby gasoline rationing capability and mandatory demand restraint measures that can be imposed if needed to soften the effects of a severe shortage. The Strategic Petroleum Reserve was created and is being filled.

Finally, the policy stresses fairness, which is crucial to the acceptability of all the other parts of our energy policy. An energy policy is not acceptable if it requires a few groups in our society to bear a disproportionate share of its burdens. The national energy policy, through programs such as low-income weatherization assistance and heating cost assistance, helps those who are affected most by the price adjustments necessary in this new energy era. Similarly, a portion of the revenues from the crude oil windfall profit tax are dedicated to easing the financial burden of higher oil prices on low-income consumers.

Our comprehensive energy policy is now largely in place and the results are evident. While the phased decontrol of oil has produced higher prices for domestic crude oil and refined products, it has helped lower domestic consumption of petroleum by 10.3 percent since 1978, from 18.8 million barrels per day to 16.9 million barrels per day. Drilling for oil and gas in the United States reached record levels in 1980 and the drilling rate should be even greater in 1981. Although we have not found enough oil to replace the amount we are producing, we have slowed the decline in production that has afflicted the United States since 1970. Phased decontrol of natural gas, coupled with the merger of the previously separate intrastate and interstate gas markets, has eliminated the natural gas shortages that befell the country during the winter of 1977. In 1980, for the first time since 1973, domestic natural gas production exceeded the previous year's total.

Use of alternative sources of energy is increasing. Conservation, through better use of our energy, has been successful in cutting energy waste significantly. Historically, it took roughly a 1-percent increase in our energy growth to produce a 1-percent increase in our gross national product; but over the past 4 years this relationship has been substantially altered. In real terms, the gross national product has increased by 2.7 percent per year, while energy use has risen at a rate of 1.1 percent per year. This trend should continue.

Outer continental shelf leasing for oil and gas production is proceeding rapidly. The current 5-year plan envisions leasing more acreage than was leased in the entire history of the program. Use of coal is at record levels, up over 100 million tons, or 16 percent, from 1977. Much of that increase in consumption has come from conversion of industrial and utility facilities to the use of coal for fuel. Solar energy, although still only a minor part of our energy

mix, has become economical for some uses, such as water heating, in some parts of the country. Biomass-derived energy, especially fuel alcohol, has a small but growing role in domestic energy production. Large pilot plants for synthetic energy sources, for both gaseous and liquid fuels, are in operation. Synthetic fuels plants, supported by Federal loan guarantees, price supports, and loans from the Department of Energy and the Synthetic Fuels Corporation, are now moving forward.

Research and development into new and existing energy sources continue. Some inexhaustible energy sources, such as magnetic fusion, breeder reactors, and solar energy, are under development. New and more efficient ways for industry to use energy have been discovered; new methods to increase the recovery of oil from existing reservoirs are being developed.

Fortunately, the country has not faced a drastic energy supply crisis in the past 4 years, although it did face moderate shortages of petroleum, natural gas, and coal on three different occasions. The shortages of petroleum products in 1979, sparked by the Iranian Revolution, did not have a major, immediate effect on the economy, but they did lead to passage of the Emergency Energy Conservation Act that provided renewed authority for the Department to develop gasoline rationing and energy emergency conservation plans. These plans are now being brought into a state of readiness; preparation for a cutoff continues.

Last heating season, low-income people throughout the country received \$1.6 billion to help pay their increased heating bills. Since 1973, the Federal Government has weatherized more than 960,000 low-income homes to improve their use of energy and lower their fuel bills; about 300,000 of those homes were weatherized during 1980.

The Department of Energy was created to be the focal point within the Federal Government for dealing with the adjustments made necessary by the new realities of energy. A good start has been made. Through the efforts of its 20,000 employees and under the leadership of two Secretaries, the Department of Energy is getting the job done. It is implementing national energy policy; it is constantly re-evaluating responses to our energy problems; and, perhaps most important, it is a consistent voice in the Government, in the country, and in the world, stressing the importance of rational solutions to energy problems.

There is no one "energy crisis"; the United States faces a number of energy-related problems. In the short term, those problems will continue to threaten our economy, our national security, and the well-being of our people. But in the longer term, the outlook is much brighter. The United States may never attain complete energy self-sufficiency, but the initiatives of the past 4 years have established a foundation upon which to build energy security.

Current Conditions

The domestic energy situation improved during 1980. Demand for energy was stable in the United States and petroleum use actually fell, as energy consumers responded to higher energy prices. Domestic energy supplies improved somewhat, although discoveries of oil did not replace the supplies used during the year. World energy prices were fairly stable for most of 1980, but, at the year's end, the conflict between Iran and Iraq precipitated increased oil prices and great uncertainty about future price changes. This section presents the Department's assessment of current conditions both for the United States and other industrialized nations, first with respect to consumption of energy, and then with respect to energy supplies.²

²The statistics for 1980 used in this chapter are a combination of reported statistics for most of the year—usually three quarters—and projections for the remainder of the year.

Current Energy Consumption

United States Energy Consumption: In 1980, the total amount of energy used in the United States fell slightly from 1979 levels, which in turn had only shown a slight increase from 1978. The United States used about 37.6 million barrels per day of oil equivalent in 1980, compared to 39.0 MMBDOE in 1979 and 38.7 MMBDOE in 1978. Our experience in 1980 thus marked a clean break from the preceding quarter century, when U.S. energy use grew by about 3 percent per year. (Figure 1-1 depicts the domestic energy sources and uses for the year 1980.) In 1980, petroleum products accounted for 16.9 million barrels per day, natural gas for 9.7 MMBDOE, coal for 7.3 MMBDOE, nuclear energy for 1.3 MMBDOE, and solar and renewable sources provided 2.4 MMBDOE. The slowdown in the economy accounted for some of this change, but so did our changing ways of using energy.

Figure 1-1—U.S. energy sources and uses in 1980 in millions of barrels per day of oil equivalent (MMBDOE)

Figure 1-2—U.S. petroleum product consumption, 1971-1980 (preliminary estimate)

The higher price of oil forced more efficient use of this scarce resource. The United States used 6.2 billion barrels of oil in 1980, or 16.9 million barrels per day. This level compares with 18.5 million barrels per day used in 1979 and with 18.8 million barrels per day in 1978. Petroleum use over the past 10 years is shown in Figure 1-2.

In 1980, there were no major problems of gasoline availability, and the price of gasoline, although sharply higher than in 1979, was stable from early spring through the end of the year. Gasoline use still fell sharply. This price-induced decline in demand from 1979 levels appears to have been brought about by the public's switch to more efficient cars and driving patterns. Over the course of the year, gasoline consumption averaged 400,000 barrels per day lower than 1979 and 800,000 barrels per day lower than 1978. Consumption of other petroleum products also fell. Significant amounts of petroleum were added to private inventories, and about 16 million barrels of crude oil were added to the Strategic Petroleum Reserve.

Natural gas consumption in 1980 increased slightly over 1979. We used just over 20 trillion cubic feet of gas, with an energy value of about 9.7 MMBDOE. The residential and commercial sectors of the economy used 7.3 trillion cubic feet. The industrial sector used about 8.4 trillion cubic feet, and utilities used 3.8 trillion cubic feet.

Coal consumption rose sharply in 1980, from 680 million tons in 1979 to more than 740 million tons. Most of

this increase was accounted for by the increased use of coal in generating electricity.

There are no precise figures for the total amount of energy produced from the many sources of renewable energy. Hydroelectric power accounted for about 13 percent of the electricity generated in the country, displacing about 1.5 MMBDOE of primary energy. Waste wood used as fuel in the wood products industry accounted for an estimated 800,000 barrels per day of oil equivalent (BDOE). A very small amount of geothermal energy, enough to displace about 40,000 BDOE, was used to generate electricity. Use of other forms of solar and renewable energy appears to have increased. For example, the use of wood stoves and solar heating systems has clearly increased, although the precise amount of this increase is not yet known.

Electrical energy is produced from utility generating plants, which in turn use some other form of energy to produce electricity. Electricity is, therefore, not counted in the primary energy figures used above. Those figures include the primary energy—from oil, natural gas, coal, nuclear fission, geothermal, or hydropower—required to generate electricity. Consumption of electricity in the United States increased slightly in 1980 to a total of about 2.1 trillion kilowatt-hours.³ About 39 percent of this elec-

³A kilowatt, 1000 watts, is a measure of the rate at which energy is produced or used. A kilowatt-hour is a measure of the actual amount of energy used. The relationship between these two terms is similar to the

tricity was used in industry, 27 percent in the commercial sector, and 34 percent in residences. Generation of this electricity required primary energy equivalent to 11.3 million barrels per day of oil.

Energy Consumption Outside the United States: The non-Communist industrialized world other than the United States used an estimated 38.7 MMBDOE of energy in 1980.⁴ This represented a slight decrease from 1979 total energy use. Petroleum use amounted to 22.1 million barrels per day, or about 57 percent of total energy use. This percentage, and the shares of each of the other major sources, was roughly equal to the distribution in 1979.

Current Energy Supply

During 1980, the total domestic supply of energy increased slightly; foreign production of energy remained about the same, though crude production fell slightly. For the United States and its allies, dependence on imported oil remains a substantial problem.

U.S. Energy Supply: The United States produces a vast amount of energy every year, 31.9 MMBDOE in 1980, or more than any other country. We are the third largest oil-producing nation in the world, the largest producer of natural gas, the largest producer of coal, and the largest producer of electricity from nuclear power. We produce about 80 percent of the energy we use, compared to an average of 48 percent in other industrialized non-Communist countries. Japan, for example, produces only 12 percent of the energy it requires.

Domestic production of crude oil and natural gas liquids⁵ increased slightly in 1980 to 10.3 million barrels per day, up from 10.2 million barrels per day in 1979. This small increase in the level of production, combined with the greatly decreased demand for oil, lowered the net amount of oil imported into the United States by more than 20 percent, from 7.9 million barrels per day in 1979 to

only 6.3 million barrels per day in 1980.⁶ Table 1-1 shows net petroleum imports during the period 1971-1980.

Table 1-1 — U.S. net oil imports

Year	Imports ¹
(millions of barrels per day)	
1971	3.7
1972	4.5
1973	6.0
1974	5.9
1975	5.8
1976	7.1
1977	8.6
1978	8.0
1979	7.9
1980 ²	6.3

¹ Net crude oil and petroleum product imports, including imports for the Strategic Petroleum Reserve.

² Preliminary estimate.

The decrease in the amount of imported oil improved the U.S. trade balance by about \$19 billion, compared to what it would have been had demand for imports not been reduced. Because the price of oil during 1980 was sharply higher than it was in 1979, however, the total U.S. oil import bill increased from about \$60 billion to about \$80 billion.

The sources of imported oil used by the United States in 1980 are shown in Table 1-2. No single country directly provided more than 19 percent of our supply of imported oil. Direct imports from nations in the Organization of Petroleum Exporting Countries (OPEC) accounted for about 62 percent of our imported oil. Petroleum products imported from non-OPEC countries, but made from OPEC crude oil, probably accounted for about an additional 13 percent.

Domestic production of natural gas remained close to the 1979 level of 19.5 trillion cubic feet. Also encouraging was the increase in the amount of proven domestic gas reserves added in recent years. Exploratory and development drilling was up over 20 percent from 1979. The increase in drilling, discoveries, and production was spread widely across the country, coming from new discoveries as well as from older fields, from the Overthrust Belt of the Rockies as well as fields in and near the Gulf of Mexico. Domestic production accounted for 95 percent of natural gas consumption; the balance was imported through

relationship between miles per hour and miles. A kilowatt is actually 1000 joules (a measure of energy) per second. Thus, kilowatt and miles per hour show rates—amounts per time periods. Kilowatt-hours, like miles, show amounts: the amount of energy actually produced or the distance actually traveled. The amount of electricity produced by a generating system is measured in kilowatt-hours because this shows how much electrical energy was produced. The capacity of a generating system is measured in kilowatts. This shows the peak output the generating system could provide at any one time.

⁴As used in this chapter, the industrialized non-Communist world outside the United States will mean the member-nations of the International Energy Agency, plus France, Finland, and Iceland. Nations in the International Energy Agency are Australia, Austria, Belgium, Canada, Denmark, West Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

⁵ Natural gas liquids as used in this context mean the liquid hydrocarbons that are extracted from natural gas. Propane, butane, and natural gasoline are the principal natural gas liquids.

⁶ Net petroleum imports equal the sum of all crude oil and petroleum products imported into the United States minus all crude oil and products exported from the United States.

Table 1-2 — Gross 1980 U.S. imports of crude oil and petroleum products by country¹

(millions of barrels per day)	
OPEC	
Saudi Arabia.....	1.3
Nigeria.....	0.9
Libya.....	0.5
Algeria.....	0.5
Venezuela.....	0.4
Indonesia.....	0.3
United Arab Emirates.....	0.2
Other.....	0.1
Total OPEC.....	4.3
Non-OPEC	
Mexico.....	0.5
Canada.....	0.4
Virgin Islands.....	0.4
Netherlands Antilles.....	0.2
Trinidad and Tobago.....	0.2
Bahamas.....	0.1
Puerto Rico.....	0.1
Other.....	0.7
Total non-OPEC.....	2.7
Total imports.....	6.8

¹ These figures are gross imports based on data from the first 10 months of the year. Imports from Iran were suspended by the President on November 12, 1979. Negligible amounts of oil from Iran, loaded before that date, were received in the United States during 1980. Imported petroleum products are counted on a par with crude oil. The sources of the crude oil refined into products overseas and then imported into the United States are not known. To get net oil imports, subtract U.S. petroleum exports of roughly 530,000 barrels per day. Note: Totals do not add because of rounding.

pipelines from Canada and Mexico and as liquefied natural gas from Algeria.

Coal production reached a record level exceeding 840 million tons in 1980, 60 million tons above the previous record, set only the year before. Domestic coal not only satisfied our current demand but also produced exports overseas. The United States exported about 85 million tons of coal in 1980, 25 percent of it steam coal used in industrial and utility boilers.

Nuclear energy is used in the United States for baseload electricity generation. The primary energy displaced by nuclear powerplants in 1980 was equivalent to 1.3 million barrels of oil per day. The amount of electricity generated by nuclear plants remained about the same as 1979 levels. An additional four plants, totaling 4 gigawatts (4 million kilowatts, or 4 billion watts) were granted operating licenses in 1980. Total production of electricity from nuclear plants was 260 billion kilowatt-hours, or 11 percent of our total electricity production. The year ended

with 72 reactors licensed to operate, with a combined capacity of 55 gigawatts. Five additional reactors with a combined capacity of 5 gigawatts are nearing completion and could be licensed for operation in 1981.

Solar and renewable energy sources now contribute about 2.4 MMBDOE of energy, primarily from wood by-products and from hydroelectric power. There are indications that the use of residential wood stoves is increasing.

Alcohol from plant matter, particularly ethanol from grain, is a source of renewable energy that has been the focus of much attention. Fuel ethanol production capacity was estimated to total 80 million gallons per year at the end of 1979; at the end of 1980, that figure had doubled to 160 million gallons. Although 160 million gallons of ethanol per year is directly equivalent to only about 10,000 BDOE, it is a first step toward achieving the goals set by the President and Congress of producing 500 million gallons of alcohol fuel in 1981 and 60,000 barrels per day, or over 900 million gallons per year, by the end of 1982.

Current Energy Supply Outside the United States: World energy supplies appear to have remained about the same in 1980 as in 1979.

Oil continued to be the dominant energy source throughout the industrial world. Oil output throughout the non-Communist world fell 5.2 percent in 1980, from 52 million barrels per day in 1979 to 49.7 million barrels per day. This drop was concentrated in OPEC nations, particularly those of the Persian Gulf region. OPEC production fell from 31.5 million barrels per day in 1979 to 28 million barrels per day in 1980, while non-OPEC production rose slightly from 20.5 million barrels per day to 21.3 million barrels per day.

Iranian production fell sharply from 1979 levels even before hostilities erupted with Iraq. Total Iranian production for 1980 averaged 1.6 million barrels per day, down from 3.0 million barrels per day in 1979. Oil production in Iraq also fell sharply after open conflict began in September 1980; total production averaged 2.5 million barrels per day, down from 3.4 million in 1979. Most other nations in the Persian Gulf produced roughly the same amount of oil as they did in 1979, although Saudi Arabian production averaged 9.7 million barrels per day, compared with 9.3 million barrels per day in 1979.

Production in non-Persian Gulf OPEC nations remained roughly stable. Non-OPEC production increased slightly in 1980. Mexico increased its production to 2.1 million barrels per day in 1980 from 1.6 million barrels per day at the end of 1979.

The price of crude oil remained relatively stable through the middle of the year. Price increases were concentrated in the closing months, when prices rose because of the Iran-Iraq conflict. The average price of interna-

Table 1-3 —Average price of internationally traded crude oil in 1980

(1980 dollars per barrel, beginning of the month)	
January	\$28.55
February	\$29.72
March	\$29.72
April	\$30.27
May	\$30.74
June	\$31.56
July	\$32.00
August	\$32.62
September	\$32.74
October	\$32.56
November	\$33.34
December	\$33.31

tionally traded oil at the beginning of each month in 1980 is shown in Table 1-3.

Most other energy sources supplied about the same amount of energy in 1980 as they had in 1979. Free world natural gas production appears to have risen from 18.5 MMBDOE to 19 MMBDOE. Our best estimate is that coal production remained roughly stable at 17.5 MMBDOE.

Nuclear energy supplied an increasing amount of electricity. Its contribution in other industrialized non-Communist countries reached 1.6 MMBDOE, 8 percent of their energy production and 4 percent of their energy use. Total capacity rose from 55 gigawatts to 61 gigawatts, while production increased by 14 percent. In some nations, nuclear energy grew even more quickly. France, for example, is now operating 22 reactors with an installed capacity of 14.7 gigawatts. An expansion to 49 reactors with a capacity of 42 gigawatts is planned in 1985.

No major change was made in the use of solar and renewable energy sources. Hydroelectric power remained the greatest portion of renewable energy used in industrialized nations, where it produced a stable 5.4 MMBDOE. Brazil has made a major effort to increase the production and use of ethanol as a substitute for gasoline. Brazilian production of ethanol in 1980 reached 680 million gallons, or 18 percent of its annual gasoline requirements.

Energy Outlook

Energy used and energy supplied must remain in balance. The crucial question facing the United States and the world is whether, in the future, these two quantities will be brought into balance in ways that allow the continuation and expansion of our economies, while protecting our environment. The answer to this question is mixed.

In the near term, the non-Communist world, and perhaps the Communist bloc as well, remains dangerously dependent on oil, often from insecure sources. In the longer term, trends that have developed and gained strength in recent years provide hope that the threat of catastrophic energy shortages can be eliminated—by more efficient use of energy, by heightened efforts to produce conventional energy sources in more secure regions, by increasing stocks of petroleum, and by increased development and use of alternative energy sources.

This section summarizes the Department's current assessment of future conditions with respect to both energy demand and energy supply in 1985 and in 1990. These forecasts are taken from a departmental study of oil vulnerability.⁷ A full explanation of the key assumptions for the projections can be found in that document. Any forecasts are, of course, highly speculative. The record for energy forecasts is filled with predictions that have fallen wide of the mark, but these projections represent our best judgment at this time.

Future Energy Consumption

The demand for and eventual consumption of energy depends critically on its price. Because of its predominant role in the industrialized world's energy supplies, the price and supply of oil will be crucial to future levels of energy consumption.

Future U.S. Energy Consumption: Our best estimate is that energy consumption in the United States will grow from 37.6 MMBDOE in 1980 to 41.1 MMBDOE in 1985 and then to 43.6 MMBDOE in 1990. The United States, under the influence of higher prices, will continue to improve the efficiency with which it uses energy. Figures 1-3 and 1-4, respectively, show projected U.S. energy sources and uses in 1985 and 1990.

Petroleum consumption in 1985 is expected to be 17.6 million barrels per day, assuming a crude oil price in 1980 dollars of \$38 per barrel. This is a reduction of 850,000 barrels per day from 1979 and of 1.25 million barrels per day from 1978, the year of our record consumption of oil. Assuming oil costs \$43 per barrel in 1980 dollars, petroleum use should decline still further to 15.6 million barrels per day by 1990.

By 1985, the decrease in petroleum consumption will occur most strongly in the transportation sector; oil use is also expected to decrease in the commercial and residential sectors. After 1985, however, additional substantial reductions in oil consumption will be achieved in the utility and

⁷U.S. Department of Energy, Office of Policy and Evaluation, *Reducing U.S. Oil Vulnerability: Energy Policy for the 1980's*, November 1980 [DOE/PE-0021].

industrial sectors as well as in transportation. Smaller reductions are expected elsewhere.

Consumption of natural gas is expected to fall from 9.7 MMBDOE in 1980 to 9.3 MMBDOE in 1985 because of declining domestic production. It will then climb back to 9.9 MMBDOE by 1990. After 1985, increased conventional gas production resulting from higher levels of drilling and exploration and the appearance of significant supplies of unconventional gas will enable gas use to increase. Residential and commercial gas consumption will remain relatively constant over the next decade, and the increased requirements for gas in the industrial sector will be offset somewhat by a reduction in gas use by utilities.

The consumption of coal will increase sharply over this period. It will grow from about 7.3 MMBDOE in 1980 to 9.2 MMBDOE in 1985 and then upwards to 11.6 MMBDOE in 1990. Utilities and industry will each increase their coal use by about 60 percent during the next 10 years. By 1990, about 0.5 MMBDOE of coal will be used in the production of synthetic oil and gas.

The contribution of solar and other renewable energy sources will increase slightly, from 2.4 MMBDOE to 2.6

MMBDOE by 1985. That figure should climb to 3.0 MMBDOE in 1990. By 1990, the renewable energy used to generate electricity will climb from 1.5 MMBDOE to 1.7 MMBDOE. Another 0.5 MMBDOE of increased renewable energy use will be spread nearly equally through the other sectors.

Use of electricity will rise sharply in both periods. Today about 3.4 MMBDOE of electrical energy is generated from about 11.6 MMBDOE in energy inputs. By 1985, production of electricity will rise to 4.1 MMBDOE; by 1990 it will reach 4.8 MMBDOE. The absolute increase in electricity consumption will be shared fairly evenly among the industrial, residential, and commercial sectors.

Future Energy Consumption Outside the United States: Total energy use in other non-Communist industrialized countries is expected to increase from 38.7 MMBDOE in 1980 to 41.5 MMBDOE in 1985 and to 44 MMBDOE in 1990.

Oil use is expected to stay about the same in absolute terms, although its share of the total energy used in those countries will fall from 54 percent in 1980 to 43 percent in

Figure 1-3—Projected U.S. energy sources and uses in 1985 in millions of barrels per day of oil equivalent (MMBDOE)

Figure 1-4—Projected U.S. energy sources and uses in 1990 in millions of barrels per day of oil equivalent (MMBDOE)

1990. Other industrial countries may find it more difficult to cut petroleum use than the United States because their economies, long accustomed to energy prices that are higher than those in the United States, use energy more efficiently than we do, particularly in the transportation sector.

Natural gas consumption is expected to increase as this premium fuel comes to play a larger role in other economies, similar to the one it has long played in the United States. Its use may grow by 20 percent by 1985, although its share of total energy consumption in other nations will still fall short of the 25 percent it provides the United States.

Coal consumption will increase by about 18 percent by 1985, and by an additional 15 percent by 1990. This increase will come in both the industrial and the utility sectors.

Use of solar and other renewable sources is not expected to increase markedly during this period in industrialized countries. Less developed countries, however, may make progress in using decentralized renewable energy sources in their economies.

The use of electricity is likely to increase substantially. Growth in consumption should be in the area of 20 percent by 1985. By 1990 the percentage increase over the decade is likely to range between 45 percent and 50 percent.

Future Energy Supply

Overall, the non-Communist world is expected to produce slightly more energy in 1985 than it did in 1980, and slightly more in 1990 than in 1985. The shares of various energy sources will begin to shift, however, as oil will become a less important factor in worldwide supplies.

Future Energy Supply in the United States: The United States will produce only slightly more energy in 1985 than it does today. Despite an unprecedented level of drilling and exploration activity, domestic oil production is expected to decline over the next few years, but the extent of the decline is the subject of great controversy. Our estimates are based on the middle of the range of projections. We estimate that total production of oil and natural gas liquids from the United States in 1985 will be 8.²

million barrels per day, compared with the current level of 10.3 million barrels per day. By 1990, production will decline further, to 8.4 million barrels per day. Most of the decline will come from declining production of conventional oil from the lower-48 states. Because of poorer returns to drilling, lower-48 conventional oil production is expected to decrease from 7.3 million barrels per day in 1980 to 5.7 million barrels per day in 1985 and 4.8 million barrels per day in 1990. Pipeline deliveries of Alaskan North Slope production should remain steady at about 1.5 million barrels per day through 1990. The remaining offsetting production increases will come from enhanced recovery projects, shale oil, and synthetic coal liquids. Enhanced recovery should contribute 0.3 million barrels per day in 1985; by 1990 the figure will rise to 0.7 million barrels per day. About 0.3 million barrels per day can be expected from oil shale and nearly the same amount from synthetic coal liquids by 1990.

A significant share of our oil requirements will continue to be imported. In 1979, the United States imported 7.9 million barrels of oil each day. While that figure fell drastically to 6.3 million barrels of oil per day in 1980, we estimate that, assuming no significant changes in current policies and programs, imports are likely to increase in 1985 to 8.3 million barrels per day. As enhanced oil recovery, shale oil, and coal liquids production increase toward the end of the decade and total demand for petroleum products drops, imports will fall again to 6.7 million barrels per day in 1990.

Total production of natural gas in the United States should fall from its current level of 9.3 MMBDOE to 8.4 MMBDOE in 1985, before climbing to 8.6 MMBDOE in 1990. Conventional production methods currently account for virtually all the natural gas produced in the United States. Synthetic natural gas produced from naphtha provides an additional 0.2 MMBDOE to domestic supplies. By 1985, conventional production will fall to about 8.1 MMBDOE. In 1990, the level of total conventional production will be about the same as experienced in 1985, with gas brought from the Alaskan North Slope through the Alaska Natural Gas Transportation System, which is expected to become operational in 1986, offsetting the expected decline in lower-48 production during the period.

Unconventional gas including production from tight sands, gas from Devonian shale, coal bed methane, and geopressurized methane, should rise from less than 0.1 MMBDOE in 1985 to 0.3 MMBDOE in 1990. Synthetic gas from coal should provide over 0.1 MMBDOE by 1990, in addition to 0.1 MMBDOE of synthetic gas from naphtha.

The remainder of our gas consumption will be provided by imports. We currently import about 0.5 MMBDOE of natural gas, mostly from Canada and Mexico, with small supplemental volumes of liquefied natural

gas from Algeria. By 1985, we expect gas imports, predominantly from the Western Hemisphere, to rise to about 0.9 MMBDOE. By 1990, they may reach a level of 1.3 MMBDOE.

Coal production is expected to increase to 10.1 MMBDOE by 1985, up from 8.6 MMBDOE in 1980. By 1990, production will reach 12.7 MMBDOE. Total domestic consumption is expected to equal 9.2 MMBDOE in 1985 and rise to 11.6 MMBDOE in 1990. The use of coal in the United States during this period is not expected to be constrained by our productive capacity; rather, the limitations on its use will result from problems associated with its consumption in environmentally acceptable and cost-effective ways.

The use of nuclear energy in generating electricity will increase significantly over the next 10 years. The amount of other forms of primary energy displaced by nuclear power will rise from 1.3 MMBDOE to 2.4 MMBDOE in 1985, and up to 3.5 MMBDOE by 1990. At the end of 1980, commercial nuclear plants operating in the United States had a total capacity of 55 gigawatts. Our best estimate now, which is based solely on the addition of nuclear powerplants that are already committed or under construction, is that nuclear capacity will increase to over 90 gigawatts by 1985 and to 125 gigawatts in 1990. By the end of the decade, nuclear energy will produce over 20 percent of the Nation's electricity.

Supplies of solar and renewable energy should grow slightly from the 1980 level of 2.4 MMBDOE to 2.6 MMBDOE in 1985 and 3.0 MMBDOE in 1990. Almost all of that energy would derive from hydropower and from biomass (in the form of pulp and paper waste, residential wood stoves, wood- and waste-powered electrical generators, and alcohol fuels). The President has set a goal of providing 20 percent of our national energy consumption by using solar and renewable energy sources in the year 2000. For this goal to be met, the share contributed by these energy sources will need to increase dramatically during the 1990's.

Future Energy Supply Outside the United States: Oil production in the non-Communist world should increase by 1985, but this forecast depends on several very uncertain propositions. The level of oil production in the OPEC nations is uncertain, affected as it is by political considerations, the possibility of unexpected disruptions, and cartel-induced supply reductions. Only a few of the OPEC nations have large reserves in relation to their current production. They could expand their output markedly, and thereby increase total OPEC production from its current level of about 28 million barrels per day to more than 36 million barrels per day. They may well determine, however, that their reserves are worth more in the ground,

appreciating in value, than when converted into other goods.

Exploration has increased in the non-OPEC countries. The prospects for increases in production are good—particularly from Mexico—but massive finds are unlikely. Furthermore, the time between discovery and development of a producing field, particularly in the adverse physical conditions where much exploration now takes place, is such that major increases are not to be expected by 1985. Production from the North Sea, expected to reach about 3 million barrels per day, will start to decline in 1983 or 1984. Conventional production from western Canada is not expected to increase by 1985, although offshore production from eastern Canada, and possibly from Arctic Canada, may boost production. China may be able to export some additional oil within the next few years, but, in view of China's domestic demand for oil, it is unlikely to contribute more than 500,000 barrels per day.

The level of oil production from the U.S.S.R. is also uncertain. Although much of the oil production of the U.S.S.R. is used within that country and its satellites, some is exported to Western nations. A decline in the amount of oil produced by the Soviets might not only end these exports, but might compel the Soviet bloc to enter the bidding for the rest of the world's oil supply. This development could have major ramifications for the price and supply of oil to the West.

Natural gas production outside the United States should increase substantially. Production in the non-Communist countries will increase by 1985 to around 22 MMBDOE from the current level of about 19 MMBDOE. We can also expect production from the U.S.S.R. and Eastern Europe to increase to about 9 MMBDOE, a large amount of which may be exported to the West.

The rest of the non-Communist world now produces 10 MMBDOE of coal. This figure should increase to about 14 MMBDOE by 1985 as Canada and Australia continue to expand their production.

Nuclear energy should more than double its contribution to other free world nations by 1985. In the near term, it will provide the major potential source of additional energy for much of the industrialized world. Production should be greater than 3 MMBDOE by 1985 and should increase to 4.5 MMBDOE by 1990.

Renewable energy will continue to provide only a small part of the industrial free world's energy supplies by 1985.

Departmental Strategy and Programs

The Nation's objective is clear: we must limit our dependence on foreign oil and reduce our vulnerability to a

disruption in foreign supplies while maintaining a strong and growing economy and preserving our environment. If we succeed, we will have improved our national security, strengthened our national economy, and assured future generations an adequate supply of energy. If we fail, the consequences could be tragic. The following section describes the Department's plan to ensure that the Nation does in fact limit its dependence on foreign oil and develop a secure energy base.

Energy Conservation and Production

The Department is pursuing many different means to improve our use of energy and to diversify the sources of the energy we use. Besides energy conservation programs, the Department sponsors major efforts in fossil energy, nuclear energy, renewable sources of energy, and electrical energy, as well as programs to protect the environment from unintended consequences of energy production. The Department also funds energy-supporting research that contributes to the development of one or more specific fuel technologies. Budget authority sought for these programs is shown in Table 1-4.

Table 1-4 — Budget authority for energy conservation and production

	1981	1982
	(millions of dollars)	
Conservation	\$ 817	\$ 922
Fossil energy	1,131	1,572
Nuclear fission	1,002	959
Solar and other renewables	1,191	1,190
(including magnetic fusion)		
Electric energy systems and storage	112	99
Environment	237	280
Supporting research	262	346
General purpose facilities	25	50
Total	\$4,777	\$5,418

Conservation: Energy conservation means making better use of energy, not merely using less energy. Because energy conservation depends on the actions of millions of individual homeowners, drivers, storekeepers, and business managers, market incentives are particularly effective. The rising cost of energy has been felt by all energy consumers, and consumers have responded by using energy more efficiently.

The most important action taken to promote conservation has been to reestablish the world oil price in the domestic crude oil market through President Carter's phased decontrol of domestic crude oil.

On April 5, 1979, President Carter directed the Department of Energy to phase out controls on domestic

crude oil by September 30, 1981. The main portion of the program began on June 1, 1979, when lower-tier oil began to be released gradually to the upper-tier level. Beginning on January 1, 1980, upper-tier oil was released from all price controls at the rate of 4.6 percent per month. Additional decontrol measures have affected special categories of crude oil, such as crude oil from small wells or from some wells using enhanced recovery techniques. By January 1, 1981, only 35 percent of the crude oil produced in the United States was covered by price controls. By June 1, that percentage will be reduced to 15 percent, before reaching zero on October 1.

This change is critical to conservation because it reestablishes a market value for energy that shows consumers the true cost of the energy they use. A similar conservation effect has resulted from the increase in wellhead prices for certain categories of domestic natural gas under the Natural Gas Policy Act of 1978, although most domestic natural gas remains subject to prices controlled below market levels.

The Department also acts to promote energy conservation through supplementing the market. To do so, it uses a wide variety of methods, ranging from informing the public of ways to save energy, to developing more efficient lighting, to providing financial assistance for weatherization and insulation, to requiring that some products meet energy efficiency standards. In each case, the Department supplements the workings of market forces so that those who use energy do so in ways that save money for them and save energy for all of us.

The Department's 1982 budget provides direct funding of \$922 million to pursue energy conservation. The Federal budget also provides funds for energy conservation notably through the Solar Energy and Energy Conservation Bank, which will request \$77 million in 1982 for energy conservation. In addition, tax incentives aimed specifically at energy conservation will provide subsidies estimated at an additional \$850 million during 1982. Table 1-5 provides the budget authority for conservation in some detail for 1981 and 1982.

The Department is taking many steps to improve the public's knowledge of energy conservation. For example, as required by the National Energy Conservation Policy Act, appliance energy labeling is going into effect. These labels inform consumers shopping for major appliances about the cost to operate different models and enable customers to weigh long-term energy savings with the purchase price. Other conservation efforts include mailing 4.5 million kits detailing energy-saving measures to people in six states in 1980, training architects and realtors in energy conservation measures, and distributing millions of copies of the new car fuel economy guides.

The Department's research, development, and demonstration activities in conservation include changes

Table 1-5 — Budget authorities for conservation programs

	1981	1982
	(millions of dollars)	
<i>Research and development</i>		
Buildings and community systems.....	\$ 88	\$ 99
Residential and commercial retrofit.....	26	31
Industrial.....	54	52
Transportation.....	108	122
Conservation multi-sector.....	26	32
Subtotal.....	302	336
<i>Grant programs</i>		
State and local.....	453	539
Energy Impact Assistance.....	62	47
Subtotal.....	515	586
Total.....	\$817	\$922

that would help the residential, commercial, industrial, and transportation sectors improve their energy efficiency. Some of the projects under development include better heat pumps, more efficient ways to produce aluminum, and the high temperature parts for economical gas turbine vehicles. The Department's budget request for 1982 includes \$336 million for research, development, and demonstration on energy conservation.

Working with other Federal agencies, states, and local governments is an important part of the Department's conservation effort. For example, the Department leads the Federal Energy Management program, which is aimed at reducing the Federal Government's own consumption of energy. The 5 million employees and military personnel of the Federal Government make up the largest single energy consumer in the country. Since 1975, conservation by the Federal Government has saved nearly 300 million barrels of oil. The Department also provides funds to state and local governments to help them conserve energy themselves and to help others conserve. The Institutional Conservation programs provide matching grants for conservation improvements in schools, hospitals, local government buildings, and public care institutions. The Weatherization Assistance program acts through states and through Community Action agencies to provide and to install insulating materials for homes of low-income people.

Direct regulation also plays a part in the Department's conservation activities. Following congressional mandates, the Department is preparing the Building Energy Performance Standards, which will require new commercial and residential buildings to meet geographically varied levels of energy use per square foot of floorspace. State plans have been accepted to implement the Residential Conservation Service, a program that requires utilities to provide conservation services to their customers. The consumer products

efficiency standards, required by legislation, will set minimum energy efficiency standards for 13 different consumer products, including refrigerators and air-conditioners.

Fossil Energy: The policy reforms noted above are critical to stimulating production of oil, natural gas, and coal, which collectively supply more than 90 percent of U.S. energy requirements. The Department's fossil energy programs encourage more oil and gas production and better use of our vast supplies of coal and oil shale in ways that are environmentally acceptable.

This year saw a significant new initiative for making better use of alternative energy sources. The Synthetic Fuels Corporation, proposed by President Carter, was created by Congress as part of the Energy Security Act. The Corporation was given the authority to provide up to \$20 billion in loan guarantees, price supports, purchase commitments, and other assistance to companies producing alternative fuels. Congress had earlier appropriated \$5.5 billion for alternative fuel development through several different acts. Feasibility studies and cooperative agreements received \$500 million in funds, and \$5 billion in appropriations were provided for loan guarantees, price supports, and purchase commitments for alternative fuels projects. Most of these funds will likely be used for fossil energy sources, such as conversion of coal to gases or liquids.

The Department's research and technology development programs for coal will focus on technologies that offer to reduce our dependence on imported oil in the near term to midterm. These include technologies that offer improved ways to use coal directly, as well as those that convert coal to synthetic liquid or gaseous fuels. Direct use of coal is being advanced by work on fluidized bed combustion, advanced flue gas cleaning systems, and coal-based mixtures. Work is also continuing on combined-cycle power systems that use coal with higher energy conversion efficiencies and better environmental performance than current powerplants. The coal-conversion activities include the development of improved technologies for converting coal to liquid fuels and to high-, medium-, and low-Btu gas. In addition, the coal research program supports the development of improved coal mining systems.

Two plants financed by the Department for converting coal to liquid fuels began operations in 1980. On May 29, the H-Coal liquefaction pilot plant near Catlettsburg, Kentucky, produced its first synthetic oil from coal. The H-Coal plant can process 200 to 600 tons of coal per day. Three weeks later, in Baytown, Texas, a plant using the Exxon Donor Solvent process began operations. This plant can convert 250 tons of coal each day into liquid fuels. In addition, plans proceeded for two other coal-conversion plants, using the solvent refined coal (SRC) process. Each

plant would process 6,000 tons of high-sulfur coal each day into the equivalent of 20,000 barrels of oil. The United States, the Federal Republic of Germany, and Japan agreed in July to build the SRC-II liquid fuel project near Morgantown, West Virginia. The SRC-I plant, to be built in Owensboro, Kentucky, will use a variant of this technology to produce liquid and solid fuels from high-sulfur coal. In total, coal research, development, and demonstration programs will receive \$1,465 million in 1982.

The Department's fossil energy programs also include research on petroleum, gas, and oil shale. Petroleum research centers on enhanced recovery of oil from known fields. Natural gas research will stress opening unconventional sources of gas, such as gas from Devonian shale, tight sands, coal seams, and reservoirs of geopressurized water and gas. Oil shale research is aimed at improving methods of producing synthetic fuels from shale, safely and economically. These programs will receive \$99 million.

The Department is also responsible for some parts of the Federal Government's program to lease Federal lands for oil, gas, and coal production. While the Department of the Interior is responsible for the actual leasing, the Department of Energy sets production goals for the Department of the Interior's leases and writes some of the regulations under which lands are leased.

Nuclear Energy: The Department's nuclear fission programs are aimed at improving the reliability, efficiency, and safety of current light water reactors; at developing more advanced forms of reactors; and at treating nuclear wastes. Funding for 1982 for nuclear fission activities will total \$959 million, compared with \$1,002 million in 1981, which includes funds for the congressionally required continuation of the Clinch River Breeder Reactor. (The Department's magnetic fusion programs will be treated in the discussion of renewable energy sources.)

All but one of the 72 nuclear reactors currently licensed for operations in the United States are light water reactors. The Department has major programs dealing with light water reactors that will improve plant safety, reduce occupational exposure to radiation, increase plant productivity, and improve the efficiency of uranium use. The Department also has established a special Technical Integration Facility at Three Mile Island to study the accident that occurred there, its causes, its aftermath, and how to clean it up. Another special program involving light water reactors is the Department's support of advanced isotope separation technology. If successful, this technology could increase the Nation's usable uranium supplies by 16 to 19 percent by making economical use of uranium currently discarded.

The Department's breeder reactor programs are exploring several possible breeder reactor systems. The liquid

metal fast breeder reactor is being studied largely through the Fast Flux Test Facility at the Hanford Reservation. This reactor reached its full 400-megawatt thermal power in late December 1980. It provides a testing ground for many aspects of this type of breeder system. The Department is also working on a water-cooled breeder system that uses relatively abundant thorium as its fuel; a demonstration reactor core is operating in the Shippingport Atomic Power Station.

In February 1980, President Carter announced the Nation's first comprehensive program for nuclear waste management. The Department is determining the best ways to store nuclear waste. Most of this work has centered on deep geologic repository sites within different types of rock. Salt domes, bedded salt, basalt, tuff, and crystalline rock forms are being studied. The Department's goal is to identify four or five sites for possible long-term waste repositories near the end of 1982. One or two licensed repositories should be operating by the middle to late 1990's. The Department is also engaged in cleanup actions involving surplus nuclear facilities, uranium mill tailings, and other sources of radioactive contamination.

Renewable Energy: Realistic energy pricing policies for oil and natural gas encourage the use of renewable energy. In addition, the Department's programs are fostering a wide variety of renewable energy sources, including all forms of solar energy, geothermal energy, and magnetic fusion. Although these sources of energy are very different, they all offer the possibility of very large or potentially inexhaustible energy supplies.

President Carter set a national goal that 20 percent of our energy use in the year 2000 will be from solar power. The Department has a variety of programs that will assist the private sector in reaching that goal. In 1982, the Department's funding for solar energy will be \$636 million. An additional \$50 million will be lent for solar projects from the Solar Energy and Energy Conservation Bank, and other Federal programs will provide another \$315 million. Tax credits for solar energy use are expected to total another \$656 million. Thus, total Federal support for solar energy in 1982 is scheduled to equal \$1,657 million, compared with \$1,286 million in 1981.

The Department has three kinds of solar programs. First, it provides information and incentives to consumers to assist technologies that are cost-effective or nearly cost-effective. For example, information is provided on burning wood, passive solar building design, active solar hot water systems, and small-scale hydroelectric power. Tax credits and other financial incentives are provided for technologies that are nearly cost-effective, such as alcohol fuels. Second, the Department seeks to stimulate cost reductions in technologies that may make significant contributions to our energy supplies by 1990. These include,

for example, solar space heating, biomass, and photovoltaics. And third, the Department is working on solar technologies with significant long-term potential, such as ocean systems, biomass plantations, and solar thermal electric power.

Geothermal energy is the Earth's heat trapped in subsurface rocks and fluids at accessible depths. During 1982, geothermal programs will receive \$91 million. The Department's programs are designed to develop better ways to exploit geothermal resources through flash steam generating plants, binary powerplant systems, and drilling improvements. The Department has a loan guarantee program for geothermal energy and is working on two geothermal resources with more long-term potential: geopressurized resources and hot dry rocks.

Low-head hydropower is a safe, clean, and proven energy source. The Department's programs will focus on the near-term potential for using dams for power generation. The principal efforts will be to minimize regulatory and other barriers to such projects. Some direct support will be provided through feasibility study loans. Low-head hydro activities will receive \$3 million in 1982.

Magnetic fusion could turn essentially unlimited hydrogen into helium and energy.⁸ Fusion technology and engineering is still at a relatively early stage, but exciting progress has been made. Congress recognized this progress by passing the Magnetic Fusion Energy Engineering Act of 1980. This act will accelerate the national effort in research, development, and demonstration of magnetic fusion systems. Magnetic fusion programs will receive \$506 million in 1982, a significant increase over the \$394 million allotted to these programs in 1981.

The Department's fusion efforts are contained in four functional areas. Confinement systems activity seeks to improve methods for containing and heating the high-temperature plasmas necessary for fusion to occur. Development and technology activities are focused on the design, construction, and operation of increasingly more complex fusion facilities. Applied experimental and theoretical studies are pursued by the applied plasma physics efforts in an attempt to predict the behavior of confined plasma. Finally, the Department's planning and projects activities provide research assistance in building the next generation of fusion devices.

The Department is building the Tokamak Fusion Test Reactor at Princeton, New Jersey, specifically to test the scientific feasibility of magnetic fusion power. The Mirror Fusion Test Facility is being built in Livermore, California. The Elmo Bumpy Torus Proof-of-Principle Experi-

⁸The Department also has programs involving inertial confinement fusion. This technology has potential military application and will be discussed as part of the Department's Defense Program, described in Chapter 13.

ment is being built at Oak Ridge, Tennessee. Each of these facilities will test a different magnetic fusion concept. In addition, the Materials Fusion Irradiation Test Facility, at Hanford, Washington, will allow us to test materials to determine their abilities to withstand the severe radiation of a fusion reactor.

Electric Energy Systems and Energy Storage: The many elements that make up the Nation's electric system may be improved in ways that result in better use of our energy resources. The Department's electric energy systems program attempts to increase the efficiency of electric systems by improving power delivery; systems control, load management, and electricity generation technologies. The 1982 budget will request \$39 million for these activities. The energy storage program is developing reliable, cost-effective, and environmentally acceptable systems that can help reduce utility use of oil and natural gas; improve the integration of intermittent energy systems, such as wind turbines or photovoltaic systems, into the electric utilities; and increase utility efficiency by maximizing the use of baseload powerplants. In 1982, the Department will request \$60 million for these programs.

Environment: The Department is committed by the Department of Energy Organization Act to "assure the incorporation of national environmental protection goals in the formulation and implementation of energy programs, and to advance the goals of restoring, protecting, and enhancing environmental quality, and assuring public health and safety." The Department's environmental programs associated with energy conservation and supply attempt to identify and to mitigate environmental problems caused by energy production and use. Beyond assessments of the effects of specific projects or technologies, the Department conducts significant research on carbon dioxide and its effects on climate, the causes and effects of acid rain, environmental problems associated with energy conservation, and the effects of exposure to low levels of radiation. The Department will request \$280 million to support these efforts in 1982.

Energy Supporting Research: The Department carries out energy supporting research to provide the fundamental scientific and engineering base on which the Nation's future energy options depend. This research cuts across the mission of technology development programs and contributes to many Departmental and national objectives. Research can be used to support several different technologies. Because of the Administration's commitment to long-term research and development, the 1982 budget seeks \$346 million for basic energy research programs, an increase of roughly 25 percent over 1981. These

programs seek to improve our knowledge of materials sciences; chemical sciences; nuclear science; engineering, mathematics, and geosciences; and biological energy research. In addition to this focus on disciplinary research, there is also an emphasis on innovative applications of new knowledge to energy problems, and on the early application and, if possible, direct commercialization of the results. Some examples of supporting research that may have immediate impact include improvement of our ability to predict the consequences of nuclear reactor accidents and possible easing of nuclear plant siting restrictions as a result of research on fission-product iodine; development of high strength steel alloys for use in automobiles; extended lifetimes for catalysts used in coal gasification, and the application of titanium diboride coatings, developed originally for erosion resistance for valves in synthetic fuels plants, to coat cathodes in aluminum reduction.

Other Energy-Related Activities

The majority of the Department's energy programs encourage better use of existing sources and the development of new sources. The Department has other energy-related programs, however. It produces large amounts of energy, markets vast quantities of electricity, collects and analyzes comprehensive statistics on energy, regulates some energy markets, and makes plans to prepare the Nation for possible energy supply disruptions.

Energy Production and Power Marketing: The Department of Energy sells and transmits electricity through five Power Marketing Administrations across the country and enriches uranium for domestic and free world customers. The products of these programs are sold at prices that are sufficient to recover the full costs of their production and distribution over a reasonable period of time. In addition, the Department is responsible for nearly 2 percent of the Nation's domestic crude oil production from the Naval Petroleum Reserves; this may be sold at competitive prices. Funds from the Naval Petroleum Reserves and the Power Marketing Administrations revert to the United States Treasury, while revenues obtained from the sale of enriched uranium offset the Department's enrichment costs. Since October 1980, oil from the Naval Petroleum Reserves has been used in trade to acquire oil for the Strategic Petroleum Reserve. In 1982, we expect revenues from these activities of \$3,250 million, compared to expenditures of \$2,685 million.

The five Power Marketing Administrations are the Alaska Power Administration; the Bonneville Power Administration, serving the Pacific Northwest; the Southeastern Power Administration; and the Western Area Power Administration. Each sells and transmits electricity produced by Federal hydroelectric generating proj-

ects, most of which are owned and operated by the Army Corps of Engineers or the Department of the Interior's Water and Power Resources Service. In 1980, the Bonneville Power Administration received substantially increased responsibilities and powers as part of the Pacific Northwest Electric Power Planning and Conservation Act. Under that act, Bonneville will play a vital role in meeting a threatened electricity shortage in the Pacific Northwest.

The Naval Petroleum Reserves were established between 1912 and 1924. In 1976, Congress directed that the reserves produce at their maximum efficient rate for a period of at least 6 years. The three Naval Petroleum Reserves produced an average of about 165,000 barrels per day in 1980. Naval Petroleum Reserve No. 1, at Elk Hills, California, was the major producer.

The Department is the only supplier of enriched uranium in the United States. It operates three gaseous diffusion plants and is designing a gas centrifuge enrichment plant, the first of which is scheduled to be in operation by 1989. Construction costs for the gas centrifuge plant will rise by \$403 million in 1982.

Energy Information: The Energy Information Administration (EIA) is a partially-independent component of the Department. Its mandate is to provide current information on all aspects of energy matters and to analyze objectively the information it collects. In pursuit of its mission, EIA has developed over 50 energy information systems dealing with a wide variety of subjects ranging from oil and gas reserves to residential use of energy. With these operational information systems, EIA prepared and published a number of applied analyses in 1980, including a congressionally requested study of the impact of Federal energy regulations entitled *Energy Programs/Energy Markets*. Other studies examined such topics as the feasibility of alternative fuel use, reducing utility oil consumption, replacement-cost pricing for energy in the residential and commercial sectors, and the costs of filling the Strategic Petroleum Reserve. The EIA also manages the National Energy Information Center, which last year responded to over 30,000 inquiries on energy-related topics from persons both inside and outside the Government. The 1982 budget provides \$127 million for the Energy Information Administration.

Economic Regulation: The Department is responsible for several congressionally imposed regulatory activities. The Department's Economic Regulatory Administration administers the prohibitions on the use of oil and gas in major new industrial and utility facilities as well as price and allocation controls on crude oil and some petroleum products. The Department also is responsible for authorizing imports and exports of natural gas and electricity. Further, the Department assists state regulatory commissions in

carrying out the standards of the Public Utility Regulatory Policies Act and, on occasion, intervenes in their state or Federal proceedings to promote those standards. The Special Counsel and the Office of Enforcement share responsibility for enforcing the Department's regulations. The Federal Energy Regulatory Commission has substantial regulatory responsibility for natural gas, oil pipelines, and electrical energy. (The work of this semi-independent body is described in its own annual report to Congress.) The 1982 budget will request \$176 million for the Department's regulatory activities, exclusive of those of the Federal Energy Regulatory Commission. This request is significantly below 1981 levels, and personnel levels will drop by more than one-third as the Department prepares for decontrol.

Energy Contingency Planning: The United States and its principal allies remain in grave danger from possible interruptions in energy supplies. Sixty percent of the world's internationally traded petroleum passes through the Straits of Hormuz. The Iranian Revolution and the ongoing conflict between Iran and Iraq have underscored the dangers of this dependence.

During 1980, the Department undertook a number of actions to improve the Nation's ability to respond to energy emergencies. The Secretary of Energy is the President's energy crisis manager for the Federal Government through his chairmanship of the Energy Coordinating Committee. The Department will act in close conjunction with other Federal agencies, especially the Federal Emergency Management Agency; with state and local governments; and with industry.

The Department's planning activities involve three types of action to reduce the effects of an oil supply interruption: increasing the supply of energy, decreasing the demand for oil, and managing the remaining supplies of energy.

The Strategic Petroleum Reserve is the most significant supply measure available for emergency responses. The Reserve now has over 107 million barrels of oil, and its managers have tested and made ready a storage capacity to accommodate 248 million barrels of crude oil. The second phase of the construction program, now under way, will expand this capacity by 290 million barrels. The 1982 budget provides \$3,684 million for oil purchases for the Reserve and an additional \$214 million for facilities and management. In addition, the Department is considering other supply enhancement activities, including actions to encourage private oil stocks, to create a natural gas reserve, or to waive temporarily regulatory impediments to full use of energy stocks.

The Department's programs aimed at restraining demand include the Emergency Building Temperature Restrictions program and the Emergency Energy Conser-

vation program. The Emergency Building Temperature Restrictions, in effect since the spring of 1979, regulate the maximum heating temperature and minimum cooling temperature of commercial buildings as well as the temperature of hot water. The Emergency Energy Conservation program, created by the Emergency Energy Conservation Act of 1979, authorizes the President in the case of critical energy supply interruptions to require the states to submit plans to meet energy conservation targets set by the President. If a state's plans are inadequate, the President may implement a Standby Federal Emergency Energy Conservation Plan for that state. The Standby Federal Plan will be completed early in 1981.

Further conservation can be achieved through electricity transfers from one region to another and through replacement of oil with natural gas. Use of these possibilities is being planned by the Department with the help of the Electric Power Research Institute, the National Electric Reliability Council, the Edison Electric Institute, the National Rural Electric Cooperative Association, and the American Public Power Administration.

The Standby Gasoline Rationing Plan, submitted to Congress in June 1980 under the authority of the Emergency Energy Conservation Act and effective on July 30, 1980, is the Department's most important supply-management tool. The plan gives the President the authority to order Federal gasoline rationing in an energy emergency. The plan would provide Federal Government ration rights checks to individuals with registered vehicles, to businesses, and to priority gasoline users. These checks could be exchanged for coupons that, in turn, would be used to purchase gasoline. The implementation of the plan is now being prepared by the Department so that it can be activated on 60 days notice if needed.

The Department also has standby allocation and price control authority over refined products that are not currently subject to controls for use in time of emergency, and Also, as a member of the International Energy Agency, the United States is a party to the Agency's oil-sharing plan. In the event of a 7-percent disruption in available supply, member countries will share their oil supplies to equalize the effects of the shortage. The Agency also works with member countries to monitor the world oil markets and to respond to less drastic shortages.

The 1982 budget provides \$3,957 million for the Department's contingency planning activities. The great bulk of this money, \$3,898 million, is for the Strategic Petroleum Reserve. Of the remainder, \$35 million is for maintenance of the gasoline rationing plan and \$24 million is for activity authorized by the Energy Emergency Conservation Act.

Other Programs

The Department undertakes some activities that are not closely related to energy problems. These include the Department's general sciences programs, defense programs, international programs, nuclear non-proliferation activities, and general support functions.

General Sciences: The Department supports three general science programs; these programs are in high energy physics, nuclear physics, and life sciences and nuclear medicine. While the programs do not contribute directly to energy technology development, their basic research is vital to the growth of sciences as diverse as physics and biology.

The High Energy Physics program focuses on the forces of nature and their relationship to particle research. The Nuclear Physics program concentrates on the interactions, structure, and other fundamental characteristics of the atomic nucleus. Experiments conducted in both of these programs require the use of large accelerators such as those at Brookhaven National Laboratory, the Stanford Linear Accelerator Center, Los Alamos National Scientific Laboratory, Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, the Massachusetts Institute of Technology, and Fermi National Accelerator Laboratory to produce the energetic particles studied. These programs carry out approximately 90 percent of all such research conducted in the United States. Although the benefits of the High Energy and Nuclear Physics programs are mainly of a long-term nature applicable to all sectors of the economy, shorter-term spinoff applications in energy and other areas do occur. Examples of these spinoffs are the parabolic solar collector, advanced radiation detection instruments, superconducting magnets, and advanced applications of computers. The life sciences program, among other activities, performs important research in nuclear medicine. The 1982 budget request for these programs totals \$607 million, an increase of more than 20 percent from 1981 in support of this important long-term research and development.

Defense Programs: The Department of Energy has the sole responsibility for the design, test, manufacture, and maintenance of the Nation's nuclear weapons. The Department is also responsible for the production of necessary special nuclear materials and the management of defense-related nuclear wastes or by-products. This important work is supplemented by the Department's activities in verifying nuclear test treaty compliance and developing and implementing nuclear materials safeguards and security procedures. In addition to these nuclear weapons activities, the Department runs the Nation's Naval Reactor

Development program, a substantial effort in the development of inertial confinement fusion technology, and provides for necessary security clearance investigations by the Federal Bureau of Investigation.

The nuclear weapons program provides for the research, development, engineering, testing, and production of all U.S. nuclear weapons; maintenance of reliable weapons for their stockpile life; and retirement and disposal of nuclear weapons from the stockpile. In 1982, the weapons program will continue to provide new technology to ensure the maintenance of a modern nuclear force, and will engage in the design and development of new weapons systems in response to defense requirements. Close coordination is maintained with the Department of Defense in all of these activities, and specific weapons requirements are approved annually by the President. The Department's 1982 weapons budget request will be \$3,049 million.

The Department's Defense Programs also include funds for research on inertial confinement fusion and for development of nuclear reactors for naval use. Inertial confinement fusion ignites small quantities of hydrogen isotopes through extreme compression, which can be achieved through the use of laser beams or beams of atomic particles. This technology has potential for both civilian and military uses. The Naval Reactors Development program is a joint effort of the Departments of Energy and of the Navy to design and to develop nuclear propulsion plant reactor cores.

Total 1982 funding for all of the Department's Defense Programs is \$4,704 million, an increase of \$1,037 million from 1981.

International Programs: Energy problems in the United States are part of broader international energy issues. The Department of State has primary responsibility for conducting all of the Nation's foreign relations, but the Department of Energy plays an important role with regard to energy-related matters. The Department analyzes the international energy situation and the promotion of cooperation with other countries in research and development. An important part of the Department's activities involves the participation of the United States in International Energy Agency activities. The Agency has acted strongly in the past year to keep down its members' demand for oil by setting country-by-country guidelines for oil use. The Department has also played a major role in promoting the Alaska Natural Gas Transportation System, a project that will cross great stretches of Canada. The 1982 budget will request \$12 million for the Department's Office of International Affairs.

Nuclear Non-Proliferation: U.S. policy on nuclear non-proliferation is particularly important because of our role

as a reliable supplier of nuclear fuels to much of the free world. Under the Nuclear Non-Proliferation Act of 1978, the Department has substantial responsibilities concerning U.S. policies to limit the spread of nuclear weapons. The Department works closely with the Department of State to negotiate agreements for cooperation with foreign countries and international organizations in the peaceful uses of nuclear energy and then implements those agreements. It also participates in executive branch consideration of export licensing by the Nuclear Regulatory Commission and has the leading role in controlling exports of nuclear technology. A particularly significant event during 1980 was completion of the International Nuclear Fuel Cycle Evaluation in which the Department participated as part of an interagency committee. The Department is supporting post-evaluation efforts concerning nuclear trade. Additionally, the Department has examined a variety of nuclear fuel cycles and nuclear systems to determine if the proliferation risks of existing technologies can be reduced.

Management and Support: The Department's management and support activities can be divided into four categories:

1. Management initiatives
2. Policy analyses
3. Liaison and outreach activities
4. Technical support

The Department implemented two major management initiatives during 1980: the Planning, Programming, and Budgeting System and a coordinated approach to improving the Department's financial management. The Planning, Programming, and Budgeting System, based on systems in effect in the Department of Defense, provides the Department of Energy with a consistent program management plan for the next 5 years. The financial counterpart to this system is the Financial Management Improvement program which, in 1980, improved the administrative control of funds within the Department and ensured compliance with the audit recommendations by the Government Accounting Office, the Department's Inspector General, and other oversight organizations.

The other improvement was made in the management and administration of the Department's programs. For example, over 5,000 contract and financial assistance awards were made during 1980, three times the number awarded in 1979. To meet increases in program actions, the development of new policies to enhance the control and appropriateness of the Department's outlays received concerted emphasis in 1980. Project and financial incentive systems were defined and served as the management framework for controlling major contractual undertakings. Anticipating the highly controversial subject of organizational conflict of interest and the related issue of the proper role of contractor personnel in policy and pro-

gram development, the Department confronted these complex issues directly and issued innovative policies and guidelines. These guidelines led to the implementation of rigorous internal procedures for ensuring senior-level management review and approval of consultant contracts.

During 1980 the Department's policy analyses formed the basis for the first use of the Planning, Programming, and Budgeting System. They supported major energy initiatives in crude oil decontrol, enactment of the windfall profit tax, and passage of the Energy Security Act. Perhaps the most significant policy analysis of the year, however, was the oil vulnerability study, completed in November 1980 and resulting in the publication of a report entitled *Reducing U.S. Oil Vulnerability: Energy Policy for the 1980's*. This study is an analytic assessment of steps that can be taken to reduce our dangerous dependence on foreign oil.

Good relations with state, tribal, and local governments; consumer groups; Congress; and the public are essential to the Department's success. The Department's objectives are to provide these groups with information and to help them deal with our programs.

The Department's activities require support from lawyers, scientists, and procurement specialists. The Department also provides substantial technical information to scientists, engineers, and administrators inside and outside the Federal Government. These programs will be

increasingly coordinated through the Department's Technical Information Center.

Additional funds, totaling \$326 million, will be requested in the 1982 budget for general management and administration of the Department.

Conclusion

The United States and the world face a critical energy problem. The next few years will determine whether our modern industrial civilization can continue to grow and prosper in an era of scarcer and more expensive petroleum. The Department of Energy cannot solve the energy problem. The Nation's energy security can be ensured only by the efforts of millions of individuals, businesses, and state and local governments throughout the country. The Department of Energy can, however, play a crucial role in guiding those efforts. The policy foundation necessary to move toward national energy security is now largely in place and is already making a significant difference. The long-run outlook for our energy security has also improved greatly, but this battle is far from over. As a Nation we must continue to recognize the extreme danger of our dependence on foreign oil and make efforts to reduce that dependence the highest national priority.

Chapter 2

Conservation

Introduction

Conservation offers the quickest and least expensive means of reducing U.S. dependence on foreign supplies of oil. To be precise, one should use the term "conservation energy," because, in fact, conservation constitutes a vast domestic source of energy supply. Every barrel of oil saved is a barrel earned. In fact, it is often a barrel earned five times over because frequently one can conserve a barrel of oil five times more cheaply than one can be produced.

Energy conservation generally includes those actions or investments that improve energy efficiency. In evolutionary stages, current buildings, equipment, appliances, autos, etc. will be replaced or modified to perform at least as well while consuming less energy. Some conservation actions, however, involve direct reductions of energy demand, such as thermostat reductions or reduced travel, which actually reduce the services made available through energy use. Energy efficiency is increased when homes are insulated, or when waste heat from industrial processes is recovered and used. Efficiency in energy consumption is also increased by designing new residential and commercial structures that require less energy for heating and cooling. New industrial processes can be developed that require less energy. And, consumer goods, such as automobiles and appliances, will be replaced by models that use less energy. The amount of energy saved grows as new, energy-efficient products replace existing stock.

Not all conservation efforts need rely on individual buildings, autos, appliances, and equipment. Large-scale projects can involve entire industrial plants and integrated community systems. These integrated systems recycle pre-

viously wasted energy and use cogeneration of electricity and heat to improve the use of conventional fuel sources or, in larger systems, to substitute coal, wastes, wood, geothermal, or solar energy for oil and gas.

Conservation is already working. In the period 1950-1973, years of relatively cheap energy supply, energy consumption grew at an average rate of about 3.5 percent per year. During the 1960s, this annual rate actually topped 4 percent. In the post-oil embargo years, however, this figure fell below 1 percent and in the period 1975 to 1979 energy demand increased only 65 percent as fast as GNP.

But much remains to be done, and the Department actively stimulates and promotes conservation. DOE programs and policies seek a direct, immediate reduction in energy demand as well as increased efficiency in energy consumption by replacing current, inefficient products. Using such tools as financial incentives and assistance, research, development and demonstration (RD&D), educational materials, and standards and regulations to implement its policies, the Department works to conserve energy in the buildings, industrial, transportation, and utility sectors.

Residential and commercial buildings represent a highly fragmented sector of millions of small energy consumers. DOE programs address the problems of conserving energy within existing buildings, designing energy-efficient new buildings, and producing more efficient appliances to be used within these buildings. The tools used are incentives, grants, education, and standards. Individual buildings have a long life, so that the turnover rate is just 2 to 3 percent per year. As an incentive to consumers to purchase insulation, storm windows, caulking, and other energy-saving

home materials, the Energy Tax Act of 1978 provides tax credits of 15 percent on the first \$2,000 spent, for a maximum credit of \$300. Since tax credits cannot help those who pay little or no taxes, weatherization grants are provided to aid low-income families, and conservation grants are made to nonprofit institutions, such as schools and hospitals.

Using available technology, new buildings could use 50 percent less energy for heating and cooling than existing buildings. Emerging technologies could raise that figure to 60 or 70 percent. The Building Energy Performance Standards (BEPS) are being designed to help accelerate improvement in energy efficiency, by requiring new structures to meet certain conservation requirements.

The appliances used in buildings—refrigerators, stoves, furnaces, water heaters, air conditioners—are replaced far more rapidly than are the structures themselves. The Appliance Efficiency Standards, when fully implemented, are expected to reduce home energy consumption by 5 percent as existing stock is replaced.

The industrial sector consumes more energy than any other. Since the sector responds comparatively quickly to economic incentives, industrial energy efficiency is increasing relatively rapidly. Moreover, the sector's energy use involves widely diverse applications, technologies, designs, equipment, and plants; thus, regulation through standards is neither practiced nor appropriate. Tax incentives for energy investments, joint funding of RD&D projects, and reporting systems and target programs are used to promote the application of more energy-efficient processes and the replacement of existing inefficient equipment. DOE programs cover both generic and industry-specific technologies. Generic projects include waste heat recovery, alternative feedstocks, and cogeneration. Research is also pursued in technologies specific to such industries as aluminum, steel, paper, textiles, and food processing.

Transportation accounts for more than half of the petroleum consumption in the U.S. Fortunately, the replacement of autos occurs in a relatively short period, about 10 years. This turnover enhances the fuel conservation efforts directed at new cars. Rising gasoline prices have already caused a shift in buying patterns to smaller vehicles. The Energy Policy and Conservation Act of 1975 set Corporate Average Fuel Economy Standards that will reach 27.5 miles per gallon by the 1985 model year. While 25 miles per gallon was considered high not long ago, new models are now reaching the 35 miles per gallon mark. In addition, research into alternate power sources, such as electric vehicles, receives DOE funding. Drivers are encouraged to use mass transit, thereby decreasing the gasoline used by single commuter driving.

The Department recognizes that not all conservation programs can be administered most effectively at the na-

tional level. Since state and local governments are more familiar with local needs and desires, DOE provides funds to several programs through these bodies. The State and Local Assistance programs include school and hospital grants and weatherization grants, as well as the State Energy Conservation program and the Energy Extension Service.

Finally, recognizing that not all improvements in energy efficiency will come from large RD&D projects, the Department also sponsors grants for inventions and small-scale, appropriate technologies. Funds are provided for concept development, concept testing, and demonstration, as well as for commercialization of inventions, products, and processes. Grants are provided to individuals, nonprofit organizations, state and local agencies, Indian tribes, and small business firms.

It is now well established that conservation is quite consistent with an expanding and dynamic economy. Conservation is an active, creative form of energy supply of benefit to every consumer. For the near term, many opportunities remain to employ currently available processes, techniques, and technologies. In the mid and long terms, new technologies will steadily increase overall energy efficiencies as new buildings, appliances, autos, and equipment continually replace those that waste energy.

Buildings and Community Systems

Introduction

The nature and extent of the Government's conservation role in the residential-commercial sector may be traced to this sector's prominent characteristics. To begin with, it is both vast and energy-intensive. The Nation's stock of over 76 million buildings consumes over one-third of our total energy resources. Because most of them were not designed with energy efficiency in mind, these buildings waste about 40 percent of the energy they use. Consequently, the potential conservation yield is very large indeed.

A second striking feature of the sector is its fragmented nature. Construction occurs in a highly segmented, incremental fashion, and it is thus difficult to aggregate private research funds for energy-efficient technologies. Moreover, the way energy is used involves literally millions of actors.

The sector's regulatory environment is equally complex. Thousands of different—and often conflicting—local building codes, zoning ordinances, utility regulations, taxing authorities, and management jurisdictions constitute formidable barriers to the pursuit of conservation.

Given these characteristics, some generic Federal roles become especially appropriate. The Government can encourage and coordinate RD&D. Because it often entails high technical and/or economic risk, the Government can

share the costs. Occasionally, it is worthwhile for the Government to sponsor this, not so much because it entails risk, but because it is costly and applies to many actors, so that no individual derives enough benefit from the RD&D to justify paying for it himself.

The dissemination of knowledge of developed energy-efficient devices and systems is another appropriate Federal role. Clearly, the Federal Government is uniquely qualified to help industry and local government surmount institutional barriers. And it can develop energy-efficiency standards for new buildings and appliances, thus ensuring that new additions to the sector realize energy savings both now and in the future.

These roles are performed in the context of the following programs: buildings, consumer products, and community systems. While each focuses on a different dimension of the built environment, they are all devoted to one objective: to accelerate the development and acceptance of energy technologies and management systems that save energy while sustaining economic growth, job creation, and personal comfort.

Buildings

The Department's Buildings program promotes energy-efficient buildings by advancing technical understanding and encouraging good energy practices through education, incentives, codes, and standards. The following discussion highlights representative activities undertaken by the Buildings program.

The Department designed and built an innovative one-family energy-conserving home on the site of the Brookhaven National Laboratory. Combining passive solar design and south-facing mass walls, as well as such basic energy-saving features as triple-glazed windows and high insulation levels, the house is expected to reduce heating costs by a dramatic 80 percent. What makes the Brookhaven house particularly attractive to builders is its use of common construction materials and a design suitable for any suburban building site.

Commercial buildings also offer a number of opportunities to learn about and to demonstrate energy efficiency. Thus, DOE was engaged during the year in a study of energy use in the Park Plaza building in New Jersey. Designed with energy efficiency in mind, the 26-story, one million square foot building is equipped with 400 sensors and a roof weather station. The function of all of this elaborate apparatus is to study the energy-saving effectiveness of current or projected design standards and operational practices.

The knowledge gained from these and similar projects must be integrated into the community of those who design, construct, sell, and buy buildings. It is clear, for example, that the architectural community requires sub-

stantial re-training or new training. In one sense, the lesson of designing energy-conserving buildings simply means recapturing the essential nature of traditional design. The resulting buildings thus accommodate rather than confront their immediate environment. In another sense, the energy-sensitive architect and designer must learn to take advantage of modern technology. Whatever the case, there is much to be learned. And so, in 1980, the Department sponsored its third Summer Institute on Energy and Design for faculty members from schools of architecture throughout the country. This teaching constituency will train the next generation of architects and designers; in turn, the newly trained graduates will help to disseminate energy-conserving knowledge and practice as they assume their professions.

The application of technical information concerning building design will also be accomplished through the development of Building Energy Performance Standards (BEPS). Required by Title III of the Energy Conservation and Production Act (P.L. 94-385) as amended by Section 304 of the DOE Organization Act (P.L. 95-91) and Section 326 of the Housing and Community Development Act (P.L. 96-399), the standards will attempt to define the amounts of energy that new residential and commercial buildings should be designed to use, within the bounds of what is economical and practical. Recent congressional action revises the original schedule and calls for issuance of interim standards by August 1981 and promulgation of a final rule in April 1983, following a 12 month demonstration of application of the interim standards. The standards would apply to Federal buildings, but unless Congress votes sanctions against buildings that do not meet them, compliance will be voluntary for non-Federal buildings.

An interesting concept of an energy efficient home is the annual cycle energy system or ACES demonstration depicted in Figure 2-1. The principal component of ACES is an insulated tank of water that serves as an energy storage bin. The size of the tank required varies with the size of the house in which it is to be installed. Heat to warm the house and to heat the water is obtained from the bin during the winter by drawing in from the water (in much the same manner that the conventional heat pump draws heat from the air). This removal of heat from the water gradually turns the water into ice during winter. In summer, chilled water from the ice bin is used to provide air-conditioning without the operation of the heat pump compressor. This causes a gradual melting of the ice and thus stores heat for use in winter. It is estimated that the system can save 50 percent or more of the energy now employed for space heating and cooling and for hot water.

Public hearings on BEPS were held during 1980 in six cities; over 14,000 pages of public comment were received as a result. Additional research designed to respond to this

Figure 2-1—Field demonstration comparing an ACES house (center foreground), a solar house (right), and a convention house (left) used for control

comment was subsequently initiated. Such research included building classification and function analysis, climate research, derivation of single-family residence energy budget, development of data on 1979 new building energy use, instrumentation of actual residences, weighting-factor research, and life-cycle cost research on commercial buildings.

The Department intends to complete, during 1981, some of the research projects described above and to initiate additional ones. New projects would include the development of procedures to assure Federal building compliance at the issuance of the interim standards, newly mandated demonstrations, and development of a notice of proposed rulemaking on implementation to be issued by the Department of Housing and Urban Development (HUD).

The Department of Energy has also developed training programs and materials for the real estate sector. Early in the year, materials were prepared for the Society of Real Estate Appraisers to train members in conducting residential energy audits. These results can figure in their appraisals,

and can be made available to lenders for consideration in the issuance of loans. The National Association of Realtors plans to train an estimated 100,000 members in marketing techniques for energy-efficient homes. A series of eight workshops has already been completed in Massachusetts. Also, in early 1981, the Institute of Real Estate Managers is scheduled to train building and property managers to conduct energy audits of multi-family dwellings and commercial buildings using materials developed by DOE. One third of the Institute's membership is expected to take part. In addition, efforts will be made during the same year to educate lenders in an effort to overcome their resistance to financing innovative housing, and also to put borrowers in touch with financial institutions willing to finance innovative energy-efficient homes.

Direct information services to encourage conservation in the Nation's residential structures are being initiated through the Residential Conservation Service program. Authorized by the National Energy Conservation Policy Act (P.L. 95-619) and amended by the Energy Security Act

(P.L. 96-294), the RCS requires certain utilities to offer onsite energy audits and other services to customers in one to four unit residential buildings. Final rules guiding the development of state and non-regulated utilities' RCS plans were issued on November 7, 1979. All but four states have submitted state plans. Implementation of RCS programs in some areas began in 1980. Programs in all states are expected to be implemented in 1981.

Evaluation has shown that different delivery and marketing techniques are now required to increase the level of implementation of conservation measures in existing residential structures, multi-family dwellings, and commercial structures. Demonstration projects are currently being planned for 1981, which will make it possible to identify with greater accuracy and precision the specific problems in delivering conservation services to each target segment. These are authorized by Title V of the Energy Security Act of 1980, and will be operating under multi-stage funding. The initial projects will concentrate upon existing residential structures.

The Residential Energy Efficiency Program (REEP) is a demonstration of a new arrangement for financing and installing conservation measures in residential buildings. Installation will be contracted for by energy conservation companies and paid for by utilities, based on the value to the utility of the energy saved in the buildings. Title V of the Energy Security Act (ESA) requires the Secretary to establish this program by rule and allows the Secretary to approve up to four proposals submitted by states or local governments for such demonstrations. The Secretary may also provide financial assistance to the approved demonstrations.

The act requires an annual report on the REEP demonstrations, including their energy savings, their effect on competition, and their implications for a national program. Since planning for the program is still at an early stage, there are no results to report at this time. DOE missed the statutory deadline for publication of the proposed rule because adequate staff time was not available to meet all of the conservation requirements of the ESA which were due at the same time. DOE plans to issue for public comment a proposed rule for the program in January 1981, and a final rule in April 1981. Proposals will be received and approved by late 1981 or early 1982, depending on the schedule established in the final rule.

Consumer Products

Energy use in buildings depends not only on the quality of the building envelope but also on the quality of heating, cooling and lighting devices within the shell. Indeed, over half the energy consumed in buildings is for heating and cooling. Lighting accounts for 22 percent of energy use in commercial buildings, and major appliances for 93

percent of residential and 70 percent of commercial building energy use.

The Department's Consumer Products program is focused on the R&D of energy-efficient technologies and products that may have a high risk but potentially high energy payoff. The program is designed to encourage and to guide industry to accelerate R&D efforts and to commercialize energy-efficient products and technologies. To date, a number of advanced technologies have been developed and commercialized jointly with the private sector. For example, in a project with two companies, a solid state ballast providing a 20 to 25 percent energy savings over a conventional ballast was developed for 40-watt fluorescent lamps.

The success of the project has created an emerging commercial market for the solid state ballast within the lighting industry, and several other companies have shown an interest in producing and marketing the ballasts. The 40-watt fluorescent bulb with solid state ballast will soon appear on the Federal supply schedule of new products. In addition, the Department is working on prototypes of solid state ballasts for high intensity discharge lamps; initial results show a 15 to 20 percent energy savings.

In another project, the Department cost-shared the development of the Amana high efficiency refrigerator. This unit is comparable to conventional 18 cubic foot refrigerator/freezers, but uses only 1.8 kilowatt hours of electricity per day instead of the 3.8 kilowatt hours required by conventional refrigerators. It is expected to be available to the public in a field test demonstration in early 1981.

The blue-flame boiler was developed and designed by the Department and a private company. One of the most efficient boilers on the market, the blue-flame recirculates some exhaust products to preheat the oil for better combustion, thus producing a steady-state efficiency of about 86 percent. This compares to the average oil furnace steady-state efficiency of 70 to 72 percent. The success of the boiler has triggered large scale development of similar products among furnace and boiler manufacturers.

Currently, two kinds of heat pumps are being developed: electric heat pumps, and thermally-activated (gas- or oil-fired) heat pumps. DOE is working with private industry to develop thermally-activated pumps that can be produced in the marketplace. Heat pump water heaters such as that illustrated in Figure 2-2 can save up to two-thirds the energy used by conventional resistance-type electric water heaters.

Groundwater heat pumps now being studied show promise as a better heat source in northern climates than the air-to-air pumps. Additionally, the Department is working with the private sector in an ongoing commercialization project aimed at reducing the high costs of heat pump systems.

Figure 2-2—Heat pump water heater, which works much like a window air conditioner

Energy efficiency is also anticipated from the Consumer Products Efficiency Program established by the Energy Policy and Conservation Act (P.L. 94-163), as amended by the National Energy Conservation Policy Act (P.L. 95-619). Under this program, standards will be established for the 13 major household consumer products.

These standards are to be set at the maximum energy efficiency levels that are technologically feasible and economically justified, and will be phased in over 5 years with the establishment of intermediate standards in 1981. Proposed standards for the first nine products were published in the *Federal Register* on June 30, 1980. To date, the

Department has been developing the test procedures and working with the FTC on appliance efficiency labeling.

Test procedures were in effect for all 13 consumer products by May 10, 1978. These procedures have been continuously updated to keep them current with the state of the art and to encourage, not impede, innovative energy-saving design features being introduced into the marketplace.

Community Systems

The word "community" has a place of its own in the energy field. The essence of its meaning lies in the concept of linkage—a group tied together by some form of network. In applying the term to energy systems, community can be defined as a complex of buildings serving multiple human activities and connected by transportation, energy, and communications networks.

The Department's Community Systems program is concerned with the integration of specific issues—e.g., redevelopment plans or utility regulations—into a community-wide perspective. Thus, the program provides a management umbrella for municipal governments, utilities, and the private sector to meld buildings, transportation, utility, and industrial strategies. Such integration will result in clear community-wide action matching available energy resources and needs, and it will also complement other community priorities such as economic development and job creation.

The program has four principal goals:

1. Create effective communication links between the various actors involved in community energy systems.
2. Help develop the ability of local governments to plan and manage their energy futures.
3. Conduct R&D in promising technologies that have community-wide applications.
4. Provide a focus for Federal community assistance programs within DOE and other Federal agencies.

The specific examples detailed below depict how the Department has been moving to attain these goals.

The clear need to develop local government capacity to deal with urgent and complex energy questions is being met in the Department's comprehensive Community Energy Management program. At present, 22 diverse communities have ongoing projects in which energy management programs are being prepared. Each is progressing through several phases: organizing, energy-auditing, identifying and choosing among energy options, developing and adopting a local energy management program, and determining the energy savings. The results of these projects are to be disseminated throughout the country in 1981.

Assistance to communities experiencing or likely to experience rapid growth as a result of coal and uranium

development projects is provided under the Energy Impact Assistance program. Established under Section 601 of the Powerplant and Industrial Fuel Use Act of 1978 (P.L. 96-620), the program assists states and communities by providing 100 percent planning grants, and 80 percent site acquisition and development grants for land that will be used for housing or public facilities such as schools, health facilities, sewage and water systems, and police and fire protection. Jointly administered by DOE and the U.S. Department of Agriculture's Farmers Home Administration, the program has to date approved 92 impact areas (in 260 counties) in 24 states, and allocated \$4,556,500 for planning grants and \$37,107,200 for site acquisition and site development grants.

Introduced in 1980, "Operation Powerplay" is a peak leveling program in which a group of large commercial businesses served by the same electric utility agree to reduce their energy use during periods of peak demand. Buildings are connected to a computer in a central information center, which monitors their varying energy demands and signals one or more of them to "shed load" just before a pre-selected maximum level is reached. Tested in Southern California, the program has already demonstrated that peak demand can be reduced by up to 25 percent at no appreciable discomfort and with significant savings to users. Similar arrangements in Jacksonville, Florida and Northern Virginia are now in the planning stages.

The Department's current district heating and cooling program may serve as a final example of the community systems approach to energy conservation. The program consists of demonstration projects aimed at encouraging implementation of the technology in several U.S. cities. Funding is limited to cost-sharing of initial phases that could lead to implementation, with little financial assistance allocated for actual construction of large systems.

Several cities are investigating the possibility of retrofitting existing steam electric generating plants to provide heat for new or existing district heating and cooling systems. These cities (ranging in size from 20,000 to over 1,000,000 people) include Detroit, Michigan; Moorhead and Red Wing, Minnesota; Piqua, Ohio; Newark, New Jersey; and Philadelphia, Pennsylvania. An assessment of the potential of district heating and cooling for the entire Minneapolis-St. Paul area has shown that it is technically feasible, that it can reduce the consumption of scarce fuels by a startling 85 percent over existing heating systems, and that with municipal financing it is economically viable.

DOE and HUD plan to initiate a two phase program of financial assistance for communities to identify potential energy-saving projects and facilitate their implementation. The first phase involves grants to 20 to 40 communities for initial assessment. Where requested, the

Federal Government could provide assistance in terms of technical support or general guidance in conjunction with financial assistance. The second phase of the program will be directed at communities that need assistance in completing various technical and non-technical preconstruction tasks required to develop the data necessary for a commitment of system construction. Figure 2-3 illustrates a test device employed to measure the thermal resistance of flat insulating materials, such as fiberglass batts. Such tests are designed to measure the resistance to heat flow, air infiltration, and other characteristics of both blanket and loose-fill type insulations.

Industrial Programs

Introduction

More efficient use of energy by the industrial sector is closely linked to economic stability, job security, and industrial growth. The industrial sector accounted for over

37 percent of all U.S. energy consumption in 1979, including 20 percent of national oil consumption and 50 percent of natural gas consumption. More than two-thirds of industrial consumption went into the production of process steam and direct process heat.

Much of the equipment employed by industry was designed and installed during times of inexpensive and abundant energy supplies. Engineering designs and tradeoffs were often made in this equipment that minimized capital cost at the expense of energy consumption. Today, fuel utilization is inefficient, generally averaging only 5 to 30 percent. Increasing the energy conversion efficiency and substituting abundant for scarce fuels are the primary goals of the Office of Industrial Programs.

DOE works to achieve these goals by: sponsoring cost-shared RD&D; conducting analyses of conservation opportunities; setting industrial energy consumption targets; and implementing and deploying advanced, existing but underutilized energy conservation technologies.

Figure 2-3—Test device to measure the thermal resistance of flat insulating materials such as fiberglass batts

The RD&D elements of the program constitute more than 80 percent of program expenditures. Focus is on two basic areas: general technologies that have application across a wide spectrum of industrial processes (the horizontal approach); and technologies that are applicable to processes of specific energy-intensive industries (the vertical approach).

The horizontal approach includes efforts directed at recovery and utilization of waste heat, combustion efficiency improvement, alternative feedstocks, and industrial cogeneration. The vertical approach includes programs in high- and low-temperature and end-product processes, and agricultural and food processes. Progress is monitored annually through use of the Industrial Reporting program mandated by the Energy Policy and Conservation Act.

The program is a little more than 4 years old, and measurable energy savings of more than 2,100 barrels per day of oil equivalent are attributable to the efforts to date. One of the Department's most cost-effective programs, it has energy savings goals, believed to be conservatively estimated, of 700,000 barrels per day of oil equivalent by the mid-1980's and 2,600,000 barrels per day of oil equivalent in the long term.

Waste Energy Reduction

This subprogram seeks improvements in energy-use efficiency and the substitution of abundant for scarce fuels in processes that are common to many industries. Objectives are to achieve annual energy savings of an estimated 500,000 barrels per day of oil equivalent by the mid-1980's and 1,000,000 barrels per day of oil equivalent in the long term.

Accelerated commercialization efforts were initiated for high-temperature and high-effectiveness recuperators. Thirty-four units were installed in 1980 and are now operating.

Significant achievements were realized in the areas of cement and concrete specifications modification. The National Bureau of Standards and DOE jointly sponsored work on standards for waste material usage in blended cements and concrete. Standards with respect to fly ash were changed while those concerning slag are now in the final stages of approval.

Successful pilot plant demonstrations have been completed for converting waste polypropylene to fuel oil. Several petrochemical concerns have expressed interest in construction of full-size facilities utilizing this process and one plant is already on-line. An accelerated commercialization effort was initiated in 1980. With waste polypropylene now constituting about 300 million tons annually (used as landfill), potential savings of nearly 5,500 barrels per day of oil by the year 2000 are possible.

The initial results from a fluidized bed waste heat

boiler systems research study were very favorable. Further efforts will be made to demonstrate and commercialize this new technology. Other significant R&D efforts in 1980 include the fine tuning of the "composite" solid fuels burner for industrial boiler systems and the final product optimization for substitute polymers from waste SO_2 .

R&D efforts were continued on air-to-fuel ratio controllers, industrial heat pumps, waste gas recovery and utilization, manufacturing, and waste tire conversion. Notably, demonstration projects for the direct combustion of waste tires have been initiated.

Cogeneration

Cogeneration, in which waste heat produced in the generation of electricity is put to use, has been the subject of much interest in recent years. Cogeneration of electrical power and process heat in industrial operations is a powerful conservation technique. It has been estimated that the energy saved through additional cogeneration systems could exceed 200,000 barrels per day of oil equivalent by 1985. The total potential savings are perhaps 3 million barrels per day of oil equivalent by the year 2000.

At present, the potential for industrial cogeneration is underutilized. Where applied, it does not generally achieve large energy savings. All cogeneration systems do not have the same energy conservation potential; very significant differences may exist between the conservation potential of two cogeneration systems that convert the same amount of fuel energy to useful power and heat. Systems must be the proper size for the plant's thermal baseload and, wherever possible, should be interconnected with the utility grid.

Most current cogeneration systems use extraction steam turbine systems and some use gas turbine and diesel machines. Although steam turbine systems can use any common fuel, they are inefficient in cogeneration because the steam extracted for process use competes directly with power production. On the other hand, gas turbines and diesel engines deliver power more efficiently; but as currently applied to cogeneration, they require premium fuels. It has been estimated that the use of these available technologies will yield a maximum energy saving of 1,100,000 barrels per day of oil equivalent by the year 2000. Although the potential energy saving is attractive, there is opportunity for even larger savings with more advanced systems.

Initiated in 1978, the new industrial cogeneration program will reorient the implementation of cogeneration toward systems that offer larger energy savings while minimizing oil and gas consumption. During 1980, detailed engineering efforts for the demonstration of two advanced cogeneration systems were continued. One system employs an externally-fired gas turbine capable of operation on a wide range of fuels, including industrial solid wastes; another employs a diesel engine designed to operate with a

wide range of gaseous and liquid fuels, including petroleum residuals and possibly coal-derived fuels. These systems have applications in paper and food processing and other energy-intensive industries.

The energy savings for this subprogram are projected to be 100,000 barrels per day of oil equivalent by the mid-1980's, and 500,000 barrels per day of oil equivalent by the year 2000.

Industrial Process Efficiency

This subprogram seeks to increase the energy efficiency of industrial processes and substitute abundant fuels for scarce fuels in the most energy-intensive industries, including primary metals, glass, cement, paper, chemicals, petroleum, textiles, and agriculture and food processing. The objectives of the subprogram are to achieve an estimated annual energy savings of 100,000 barrels per day of oil equivalent in the mid-1980's and 1,100,000 in the long term.

Significant results were realized from this subprogram area during 1980. Successful commercialization of the coil coating technology was continued by the private sector without further Federal assistance. Foam finishing technology, well into the commercialization stage and one of seven industrial technologies selected for an accelerated commercialization effort, has been implemented in nine different textile mills. Sixteen units are each processing 250 million yards each of textile products annually and achieving savings of 260 barrels per day of oil equivalent.

The high-efficiency slot forge furnace, which achieves a savings of nearly 70 percent over conventional units, continues in the commercialization stage. It is also one of the technologies for which accelerated commercialization projects were initiated in 1980. To date, ten units are in operation, each realizing energy savings of 28 barrels per day of oil equivalent. By the beginning of 1981, ten more furnaces are slated to be in operation; 8,000 such units could potentially be used in the slot forging industry. Additionally, three high-efficiency arc welding power supply units are in operation. Acceleration programs were initiated for the high-efficiency arc welding power supply and for alternative powered hand tools.

In the agricultural and food processing areas, demonstrations are either under way or planned for irrigation, crop drying, fertilizer production, and food processing systems. In addition, integrated farm systems are being developed that will combine conservation techniques with the use of such alternative energy sources as wind, solar, and biomass to achieve near self-sufficiency for some farming enterprises.

Implementation and Deployment

The objective of this subprogram is to stimulate implementation of new as well as existing but underutilized

energy conservation technologies and practices by the industrial sector. The activities of the subprogram are highly diverse. Delivery systems that will involve extensive DOE resources such as the Energy Extension Service and regional offices will eventually be utilized as part of the overall commercialization effort.

During 1980, several activities were conducted in response to the National Energy Act. A study was continued to determine the relevance of the Second Law of Thermodynamics to energy-consuming processes and to various energy conservation programs. A report to the Congress was completed in January 1980. Recovered materials utilization targets were finalized for the rubber, metals, paper, and textile industries, and a feasibility study for performance standards on motors and pumps was completed. The feasibility study for performance standards on motors and pumps will soon be reported to Congress. Other equipment efficiency studies will be initiated shortly.

Various activities were undertaken in 1980 directed toward industrial assistance and awareness of technologies for energy conservation. Energy Analysis and Diagnostic Centers were continued at three universities (Pittsburgh, Tennessee, and Georgia Institute of Technology) and three additional centers have been added and will be operating by early 1981. The energy conservation impact of the centers in 1981 has been estimated at approximately 330 barrels of oil equivalent per day. Specific plans for technology deployment implementation in the iron and steel, pulp and paper, and agriculture and food processing industries were completed. Technology deployment implementation plans will be initiated soon for the industrial areas of chemicals, textiles, glass, aluminum, cement, and petroleum refining.

Authorized by the Energy Policy and Conservation Act (P.L. 94-163) and National Energy Conservation Policy Act (P.L. 95-619), the industrial reporting program has continued with the publication of a final program rule and the deployment of plant, corporation, and sponsor data forms. Instruction to industry on the requirements of the new program rule was provided by a series of 12 one-day workshops, all conducted during March 1980. The instruction was provided with the objective of ensuring clear understanding by corporate and association personnel of the new reporting system, the time schedule for reporting, and the standardized forms to be used.

As part of a Department-wide commitment to the environmental aspects of energy programs, an updated environmental development plan was prepared in 1980. This document spells out specific plans for dealing with environmental, health, and safety-related concerns associated with the hardware programs supported by the Office of Industrial Programs.

The technology transfer document program was continued in 1980 with several significant publications targeted

for industrial audiences. Detailed engineering-oriented technology application manuals addressed energy conservation opportunities in computer control of industrial processes, distillation, dairy operations, the citrus industry, and the meat processing industry. Technical briefing reports and executive briefing reports notified industrial management and corporate energy program coordinators of these and other energy conservation opportunities. An industrial communications program was initiated, which will develop more effective means to deliver such technology transfer documents into the hands of their intended audiences.

During 1980, energy conservation workshops were used to convey information and direct assistance. Between November 1979 and March 1980, ten workshops were carried out in New England; emphasis was on short-term, low-cost operating and technical changes that firms can make in order to reduce their oil consumption an average of 10 percent. Conducted in close cooperation with state officials, they attracted an average of 200 participants each. State governors made personal appearances at a number of the workshops. A followup evaluation of the workshops showed that probable annual savings in plants represented by participants would be about 145 million gallons of oil within the first year. The evaluation also showed that about \$220 million was planned for capital investments by the attending companies to bring about the savings. Total oil consumed by the companies represented at the workshops was about 960 million gallons, or about 1 percent of U.S. industrial use.

In addition, a series of four workshops was held with state energy office representatives. The objective of each was to provide information on Federal programs in industrial energy conservation, promote interstate coordination of industrial energy conservation programs, and identify needs and problems at the state level that should be addressed at the Federal level.

The industrial energy conservation program is now well under way. Developmental activity is progressing in every major industrial area, and significant energy savings are being achieved. Yet, many excellent opportunities will require years before commercial acceptability and widespread market penetration can be achieved, and other promising concepts have yet to begin their developmental journey. However, the overall program structure and strategy are in place, as are the managerial mechanisms that select, monitor, fine-tune, and adjust each program element.

Transportation

The transportation sector consumes more energy from petroleum than all other sectors combined; and, in terms overall domestic energy consumption, accounts for

about 26 percent of requirements. The Department's objective is to reduce gasoline consumption by 10 percent from currently projected near-term levels and to achieve a 25 percent reduction in all forms of transportation energy from levels now projected for the mid-term.

To accomplish this, DOE—through its Office of Transportation Energy Programs—is focusing on three principal activities:

1. Research, development, demonstration, and commercialization of alternative transportation and fuel technologies.
2. Providing industry with new technologies, operational strategies, and institutional concepts that, when implemented, can significantly reduce the consumption of petroleum.
3. Preparation of informational, educational, and other outreach materials designed to foster public and business awareness of conservation opportunities and to encourage the adoption of specific transportation efficiencies.

During the coming several years, opportunities for conservation in the transportation sector will primarily involve the improved use of existing vehicles coupled with the replacement of older vehicles by newer, more energy-efficient models. Typical of the technology and other improvements expected are energy-saving tires and lubricants, better driving habits (including the expansion of carpooling), and proper vehicle maintenance.

Over the next decade or so opportunities for conservation will increase as older vehicles are replaced by newer ones. (The domestic automobile fleet turns over in approximately a decade.) During this period, further technological improvements are expected, particularly in engines, drive trains, transmissions, and tires and lubricants. All will add to tomorrow's lighter, more efficiently designed motor cars and trucks. The use of microprocessors and turbochargers should increase along with the number of electric vehicles in service. And, one would expect to see more ride sharing and mass transit in the future.

As for the long term—the end of the century and beyond—major technological breakthroughs in propulsion systems could significantly reduce the dependence of the transportation sector on petroleum fuels. At the same time, continuing advances in telecommunications and computers may reduce the need for business and business-related travel.

DOE's activities in the transportation sector are undertaken within three program categories: vehicle propulsion R&D, electric and hybrid vehicle development, and transportation systems energy efficiency.

Vehicle Propulsion Research and Development Program

Well under way as early as 1975, this program seeks to

Figure 2-4—Stirling engine mounted in 1977 Opel Rekord

develop an engine whose fuel economy is at least 30 percent better than the best 1984 internal combustion engine in a vehicle of equal performance. This engine must demonstrate an ability to meet or surpass the most stringent Clean Air Act emission standards and also demonstrate multi-fuel potential. Several studies performed in the 1970's showed that Brayton and Stirling engines possess high fuel economy potential, while at the same time meeting low emissions and multi-fuel capability.

The Brayton engine produces power by the expansion of hot combustion gases passing through a turbine that provides the useful work. A portion of the output of the turbine compresses the inlet air. In configurations under development for automotive propulsion applications, the exhaust gases from the turbine pass through a regenerator to preheat incoming air.

The Stirling engine is a continuous external combustion closed-cycle machine that converts thermal energy from the burning air/fuel mixture to mechanical work by alternately compressing and expanding a confined working

fluid, using heat rejection during compression and heat addition during expansion. The pistons in the automotive Stirling engine have two functions: they move the gas working fluid back and forth between the hot and the cold locations, and they transmit mechanical work to the drive shaft. A Stirling engine mounted in a car is illustrated in Figure 2-4. Hydrogen, used as a working gas, is not burned but is employed to transfer energy much like the refrigerant in an air-conditioner.

For the gas turbine program, contracts have been negotiated with two major industry teams. Major advances were achieved in durability testing of high-temperature ceramic materials in actual over-the-road, component rig, and engine dynamometer testing. The final designs of advanced gas turbine systems have been completed and major hardware fabrication is under way. Complete engine dynamometer testing is scheduled to begin by the end of 1981.

The heavy-duty gas turbine demonstration program is supported jointly by the Department and the Department

of Transportation's Urban Mass Transportation Administration (UMTA). DOE provides the vehicle engines, arranges for the collection of technical data, and conducts test-track experiments to obtain specific engineering data. UMTA arranges for the buses in which the engines are installed, selects the cities where they will run, and supervises the use of buses in routine operations. Five gas turbine buses, using ceramic generators, went into regular passenger service in Baltimore, Maryland, in April 1980. In later phases (in other cities to be selected by UMTA), improved engines with additional ceramic components will be evaluated. The intercity gas turbine bus demonstration program, a cooperative effort between DOE and Greyhound Lines, Inc., evaluates heavy-duty gas turbine engines under actual daily operations. Four demonstration buses currently operate on the Chicago-Louisville route.

In the vehicle systems program area, projects are under way to promote commercialization of transmission, drivetrain, accessory drive, and waste heat utilization subsystems designed to improve fuel economy. It is expected that both the diesel and alternative portions of the intercity and urban gas turbine bus demonstration will be completed in 1981, with over 8 million revenue service passenger miles. Other activities include tests on a turbocompound diesel using advanced turbomachinery, expansion of on-the-road mini-fleet evaluations of the preproduction Rankine bottoming cycle truck installation, and transfer of transmission technology to the Stirling and gas turbine automotive projects.

Electric and Hybrid Vehicle Program

Produced in large numbers at the turn of the century in the U.S., electric vehicles gradually lost their market to their competitors. A resurgence of interest in electric and hybrid vehicles began in the 1960's and has continued to the present. The chief motivation was concern over the urban environment—air and noise pollution—but it was also clear that these vehicles could offer potentially significant savings in petroleum. The importance of the latter grew as oil prices soared in the 1970's.

This interest led to the entry of the U.S. Government into the electric and hybrid vehicle field. The Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976 (P.L. 94-413), enacted on September 17, 1976, established a greatly expanded program within the former Energy Research and Development Administration, which evolved into the DOE program now under way.

DOE's program encompasses research, development, engineering, test and evaluation, incentives, and demonstration, all aimed at promoting the widespread use of electric and hybrid vehicles. Total vehicle systems, subsystems and components, batteries, and other means of energy storage are involved.

The electric-hybrid vehicle program assists manufacturing and support industries in identifying suitable markets while stimulating demand, improving performance, lowering cost, and demonstrating practicality. Five program areas are emphasized: market demonstration, vehicle evaluation and improvement, electric vehicle commercialization, hybrid vehicle commercialization, and advanced vehicle development.

Market Demonstration: P.L. 94-413, as amended, requires the demonstration by 1986 of up to 10,000 electric and hybrid vehicles. This can be accomplished in joint ventures with commercial firms, Federal agencies, and state and local governments. Demonstrations work through the marketplace by building the vehicle market and support infrastructure, by providing cash flow to manufacturers, and by being instrumental in improving the products through market influence.

In its third year of operation, the Market Demonstration project now encompasses 68 cost-sharing site operators at 94 different locations in 30 states. One site operator will have 185 vehicles in 10 locations. By the end of 1980, cost-sharing arrangements were made that added 497 vehicles to the demonstrations, bringing the total to 1,155.

Since 1978, the first year of the demonstration, the production capability of electric vehicles increased by a factor of eight, with one manufacturer now producing 60 vehicles a month. New private sector partners in 1980 included taxi operators in New York City, dealer-type operations in New Jersey and Colorado, major airlines, and others. The numbers of state and local government participants increased from 10 to 22. More than 850 new requests for applications were received during the year for participation in 1981. Two loan guarantees were negotiated with two small business electric vehicle producers to increase their production capability. Six additional formal requests were in process as the year drew to a close.

Vehicle Evaluation and Improvement: Projects using off-the-shelf technology to accelerate commercial availability of improved vehicles are involved in performance and safety standards. The market demonstration projects are renewed and updated, manufacturers' self-certification and verification test programs are managed, and state-of-the-art testing is conducted on selected vehicles. The third state-of-the-art report is being published this year. Delivery of 18 vehicles, scheduled under the first product improvement program, are being completed. So are development of two small energy-efficient air conditioning systems for electric vehicles. This project completes testing of four state-of-the-art vehicles and verification testing of four additional manufacturer self-certified vehicle models available for market demonstration purchases.

Figure 2-5—Modified AMC Pacer fourth-generation EVA electric test car

Electric Vehicle Commercialization: This project element helps to induce the commercial production of electric vehicle components and subsystems, including batteries, through accelerated RD&D. Consideration is also being given to the appropriateness of inducing large-scale commercial production of electric cars through a future cost and risk-sharing business relationship with major automobile manufacturers.

The first element addresses the components and subsystems that include motors, controllers, transmissions, propulsion subsystems, charger and charge indicators, and environmental controls. Battery development and commercialization activities are focused on lead-acid, nickel-zinc, and zinc-chlorine battery types. A rapidly growing technology base has by now been established. This has been supplemented by efforts to induce commercial production of the more promising components, subsystems, and batteries through a broad spectrum of innovative business relationships between government and industry. During 1980, discussions got under way with automotive

manufacturers that expressed serious interest in participating in the second element of the project.

DOE also provided technical and commercialization assistance of a nonfinancial nature to vehicle, subsystem, component, and battery manufacturers. This support involved commercialization studies, field test vehicle development, field testing, coordination with the utility industry, and market development assistance. The first major incentive came with the inclusion of electric vehicles in the automobile manufacturers' corporate average fuel economy numbers.

A typical electric test car is the modified fourth-generation Electric Vehicle Associates AMC Pacer shown in Figure 2-5. Weighing some 4,200 pounds, the car has a cruising speed of 44 miles per hour and a passing speed of 56 miles per hour.

Testing of the General Electric/Chrysler electric test vehicle (ETV-1) continued during 1980 at the Jet Propulsion Laboratory. Testing of the batteries developed under the Near-Term Battery Program is scheduled to commence

in 1981 with this and other vehicles. Full-size experimental nickel-iron and nickel-zinc battery testing with the South Coast Technology, Inc. Volkswagen Rabbit demonstrated a 30 to 80 percent increase in range over similar vehicles. The installation of a zinc-chloride battery in a Gulf & Western subsidiary electric vehicle was also well under way as the year came to an end; testing is being scheduled for the near future. Under a cost-shared contract with the Eaton Corp., an a.c. propulsion system was developed and delivered; such a motor enjoys cost and maintenance advantages over d.c. systems.

The Road Load Simulator, a one-of-a-kind facility for programmable testing of electric and hybrid vehicle propulsion systems and components, became operational during the year. It enhances the low-cost, high-quality testing capabilities of the program by providing an important tool for evaluating various competing designs and for determining which options are most promising for continued development.

Argonne National Laboratory's National Battery Test Laboratory became operational in 1980. It was established to test experimental nickel-zinc, nickel-iron, and lead-acid battery modules.

Hybrid Vehicle Commercialization: This project seeks to induce mass production of cost-competitive hybrid vehicles with a range capability comparable to internal combustion engine vehicles. Phase I preliminary design studies were completed during the year for the Near Term Hybrid Vehicle Development Program. In Phase II vehicle development, two hybrid integrated test vehicles are being built. These vehicles will demonstrate the potential for petroleum savings from 40 to 70 percent over conventional vehicles of equivalent size and performance. During 1980, system design and specifications for the hybrid test vehicle were completed. In addition, advanced hybrid propulsion system studies identified propulsion systems that would be suitable for five different classes of vehicles using technology that could be developed by the mid-1980's.

Advanced Vehicle Development: The objective here is to develop a general-purpose electric or hybrid vehicle system that is fully competitive with internal combustion engine vehicles and that requires no petroleum for operation. It appears probable that such a vehicle could be commercialized in the late 1990's.

The Garrett AiResearch Company electric test vehicle (ETV-2) battery-powered car is currently undergoing characterization testing. This vehicle features a high-speed fly-wheel and body and chassis of composite material.

It is expected that testing of functional models of an advanced d.c. brush-type motor and a brushless electronically-commutated, disk-type motor will verify the perfor-

mance, cost, and weight improvement potential of these advanced concepts. The technology fabrication required for dynamic testing of inductive coupling to electrified roadways was nearly completed by the end of the year at Lawrence Livermore Laboratory. To characterize fully the system, dynamic tests are to be carried out in cooperation with the Department of Transportation during 1981.

Potential: In keeping with its 1979 stated objective to produce electric vehicles by the mid 1980's, in January 1980, General Motors announced the establishment of an electric vehicle project. In addition, small businesses are engaged with an ever-increasing number of electric vehicle users inside and outside the DOE program, and a number of new vehicle models, ranging from two-seater sports cars to 1/4 ton trucks, are becoming available. These events, along with the other efforts of DOE and non-government organizations, are creating a rapid expansion of efforts to develop and commercialize both electric and hybrid vehicles.

Transportation Systems Energy Efficiency Programs

The Transportation Systems Energy Efficiency programs were established to promote the acquisition of the most efficient transportation equipment available and the usage, operation, and maintenance of equipment, vehicles, and systems in ways that maximize energy efficiency. The 1980 national gasoline consumption target of 7 million barrels per day is being achieved as a result of higher gas prices, unprecedented consumer demand for fuel-efficient new cars, and greater awareness among motorists regarding ways to reduce gasoline use. These programs seek to reduce transportation energy consumption levels by 10 percent below currently projected consumption levels. A final objective of the programs is to prepare the transportation sector to deal with conditions that would accompany supply disruptions.

Fuel Economy Information: To help create a more fuel-efficient vehicle fleet, the New Car Fuel Economy Information program provides prospective purchasers with fuel economy information on all automobile and light-duty truck models. The program assists the new car buyer in choosing the most efficient automobile by providing comparable fuel economy information. Approximately 16 million copies of the 1980 *Gas Mileage Guide* were printed and distributed to 29,000 new car dealers. The 1981 edition of the *Guide* has been redesigned for improved visual impact.

The program office is currently evaluating measures for improving consumer knowledge and acceptance of the Government's fuel economy programs. Evaluation results should make fuel economy information more useful and

realistic by eliminating the disparity between the Environmental Protection Agency's fuel economy estimates and actual in-use fuel economy data. The analysis will also support improved regulations, conservation policy, and program materials related to automobile and light-duty truck fuel economy.

Voluntary Truck and Bus Fuel Economy Program: Membership in this program to improve the fuel-use efficiency of commercial vehicles increased during the year from 250 to over 325 members from industry, trade associations, labor unions, press, and 21 state energy offices. Members are committed to participating in the development and support of fuel-efficient products and programs for driver training and conservation. Twenty-seven seminars and owner-operator conferences were conducted in truck dealer showrooms in ten states in the south, northeast, and mid-west regions of the country. A fuel economy exhibit was developed for display at five major industry trade shows. The quarterly newsletter, "Fuel Economy News," featuring articles on industry conservation efforts and updating new truck and bus fuel economy technology, was distributed to over 3,200 firms and individuals.

A national publicity effort is scheduled to begin in 1981 to promote this voluntary program to the trucking industry. Increased trade press recognition of the program, expanded membership, and professional relationships between DOE and target trucking industry groups are expected to result, increasing the effectiveness and marketability of program information.

A Government Accounting Office report concluded that the program is "effective" in bringing fuel economy practices and technology to the attention of the trucking industry. It urged that even more emphasis be given to achieve its full potential. Within the constraints of available resources, new initiatives are directed toward achieving the report's recommendations.

Driver Efficiency Program: Individuals and organizations are provided with information that can help reduce the use and the overall cost of motor fuel while maintaining mobility. The information covers trip planning and vehicle maintenance, purchase, and operation. Key networks and their principals receive direct education and outreach materials that range from intensive instruction in administration, implementation, and education for instructor training to single-copy distribution of one page pamphlets.

Under the aegis of the White House Energy Efficiency Program, two efforts started during the year. One, a Driver Energy Conservation Awareness Training (DECAT), is an intensive 3-day course that combines classroom, laboratory, and instrumented behind-the-wheel instruction in fuel-efficient vehicle use. The other, known as Teach-Ins, pro-

vides one-day lectures and demonstrations of fuel-efficient vehicle use and program implementation.

Both efforts have generated several thousand instructors and students in 45 states who are now well versed in the methods of saving motor fuel. DECAT produced 300 instructors and over 3,000 students, while Teach-Ins trained 2,000 managers and implementers.

The structure developed ensures that each person taught will teach many more; it has been successfully followed by organizations from Federal, state, and local government, industry, and business. Early results indicate savings of 10 to 14 percent as well as improved safety and positive public image attributable to these programs.

Both activities will continue in 1981 to develop new and improved education materials, to identify and to verify (through research) savings techniques, and to study driver information needs and design driver feedback devices. It is planned to commercialize effective concepts for educating drivers about fuel use. A monograph series will be distributed to program members to facilitate information transfer. A truck DECAT program, a police DECAT program, and a Federal DECAT program are to be initiated, while existing DECAT facilities will be expanded by one-fourth. Program evaluation will determine program effectiveness and final savings.

Ridesharing: The Department of Energy and the Department of Transportation are cooperating to promote and advance carpools, vanpools, and mass transit. Since 1976, DOE and its predecessor agencies have promoted the elimination of institutional barriers to carpools and vanpools, the development of vanpool and carpool programs in the Federal Government, technical assistance to state energy offices and local authorities, the commercialization of vanpools, and the use of ridesharing. Vanpools have proved to be the key to ridesharing growth during times of plentiful gasoline, while during gasoline shortages carpools are the key to significant energy savings (from 100,000 to 500,000 barrels per day).

In 1979 and 1980, the Department was very successful in attracting private sector investment in vanpools. As a result, Hertz, Ford, and Chrysler launched national advertising campaigns during the year. Also, Riggs National Bank, Washington, D.C., became the first bank to offer such financing in a major urban market.

Within the Federal Government, DOE established a major ridesharing campaign, and conducted 30 workshops throughout the Nation to train newly assigned employee transportation coordinators. This latter activity has become the responsibility of the General Services Administration.

Vanpools were classified during the year as a Priority One user under the gasoline allocation plan to assure vanpools gasoline in the event of severe shortage. To be fully

effective, each state must take certain actions; DOE has developed a program to assist them in this endeavor. DOE also assisted the President's National Task Force on Ridesharing in creating additional interest at the state level in setting vanpool gasoline priorities, improving insurance availability, and assuring the continued production of the large 12-15 passenger van despite the downsizing of vans planned for the post 1983-1985 years. A typical vanpool program undertaken by DOE, an industrial firm, and a regional transportation district is illustrated in Figure 2-6.

Nationally, the number of vanpools doubled in 1980. If vanpools were as effectively promoted as in the three leading vanpool states—Texas, California, and New Jersey—the national growth rate would be even higher. DOE expects the national vanpool marketing campaigns of vanpool leasing companies (with their thousands of outlets) to contribute substantially to vanpool growth in the early 1980's. Also, DOE developed a new publication, *Starting a Driver Owned and Operated Vanpool*, which is expected to aid the growth of vanpool use.

In 1981, the Department plans to emphasize the development of contingency strategies for increasing ridesharing nationally during severe gasoline shortages. These strategies will take advantage of the surging interest in carpools by making carpool matching services readily available to tens of millions of commuters on a 1-2 month notice and by using all mass media channels available to the Government.

Systems Efficiency Programs: These programs were set up to develop and commercialize conservation technologies for highway, air, marine, pipeline, and railroad transportation modes. Studies of energy use and conservation opportunities were completed for each mode during the year. One conservation R&D project involved an alternative fuels test program for medium-speed diesels used by railroads and inland waterway vessels.

An effort to identify power plants for future locomotive application is to be completed in 1981. Technical reports published in these areas include *Alternative Energy Sources for Non-Highway Transportation*

Figure 2-6

Cooperative pilot van-pool program operating in Rocky Flats, Colorado with DOE, industry and the regional transportation district

(June 1980), *Energy Study of Railroad Freight Transportation* (August 1979), *Pipeline Bottoming Cycle Study* (June 1980), and *Validation of the Application of Rankine Bottoming Cycle Technology to Marine Diesel Engines* (July 1980).

The development, publication, and distribution to 8,000 users of *A Shipper's Guide to Energy Conservation*, were accomplished during 1980. Also, an analysis of the net energy impacts of proposed deregulation of the truck and railroad industry was conducted by the Department.

Systems efficiency programs also promote conservation opportunities for intercity passenger travel. Work has so far concentrated on improving the energy efficiency of commercial aircraft operations and the regulatory environment of the National Airspace System in which commercial aircraft must operate. For airport operations, work was completed during the year on a feasibility study of extended aircraft towing. It was concluded that aircraft towing is not only technically and operationally feasible, but would result in substantial fuel savings and reduction in aircraft emissions and noise. Based on these results, work has begun on the planning phase of the program, leading to the eventual demonstration of extended aircraft towing at one U.S. airport. Other program efforts promote conservation through the implementation of improved airframe and engine maintenance procedures.

To improve the efficiency of the National Airspace System, a study identified various fuel-inefficient Federal Aviation Administration regulations and Air Traffic Control procedures. Results of this study led to the analysis of fuel penalties associated with noise abatement procedures now in operation at U.S. airports. Also, fuel benefits were quantified of aircraft operations in a direct routing area navigation mode.

This activity also investigated various means by which transportation energy can be conserved through the use of current telecommunication technologies. Potential fuel-conserving possibilities include home-based or satellite work centers, teleconferencing, and area-wide traffic signal coordination.

Technical reports published in the intercity passenger area include *Examination of Commercial Aviation Operational Energy Conservation Strategies*, *Identification of Federal Aviation Administration Regulations and Procedures that Impact Fuel Consumption*, *Aircraft Towing Feasibility*, and *Initiatives for Conserving Transportation Energy through Telecommunications*.

Preparations were made during 1980 for a possible future supply interruption. Under provisions of the Emergency Energy Conservation Act of 1979, a methodology was developed for establishing state gasoline conservation targets. Voluntary targets were issued to each state for all four quarters of 1980. Also in accordance with provisions

of the act, transportation components of the Standby Federal Emergency Energy Conservation Plan were developed, and program representatives participated in the public hearings held on the proposed measures. Technical materials to aid the states in the preparation of new plans were prepared and distributed to the states.

The development and assessment of contingency planning measures in support of the Emergency Energy Conservation Act, and the development of methodologies for setting state conservation targets for gasoline and perhaps other mobility fuels, will continue to receive emphasis. Associated with the contingency planning program will be a continuing State and Local Transportation Conservation Technical Assistance Program designed to transmit conservation information and stimulate state, local, and regional activity. In addition, demonstration programs will be initiated for organic Rankine bottoming cycle application to marine diesels and the towing of commercial aircraft at airports. Research will continue testing the application of alternative fuels to medium-speed diesels (railroad and marine). New projects concerning conservation in freight intermodal operation and marine transport will be initiated.

The Transportation Systems Program also plans, in 1981, to increase DECAT capacity by 33 percent, establish state-level workshops on implementing transportation conservation programs, and commercialize feedback devices for retrofit and new automobile markets. In its outreach efforts, the program will distribute new vehicle purchase data to fleet purchasers, expand truck dealer and truck stop information programs, implement the updated marketing and outreach program for expanding outreach to truckers other than major fleets, and increase *Gas Mileage Guide* dissemination by 4 million copies. The Driver Efficiency and Truck/Bus programs will be evaluated.

The Federal Energy Management Program

Roughly five million people in number, the Federal workforce occupies 420,000 buildings, drives 100,000 automobiles, and operates 400,000 mission or tactical-related vehicles. Since 1975, this workforce has cumulatively saved 295.6 million barrels of oil equivalent. In turn, this saving translates into enough energy to heat nearly 2.9 million average American homes for one year, and approximately 5.6 billion dollars. In large measure, this substantial savings yield is the result of agency participation in the Federal Energy Management Program.

Over the next 10 years, the program can yield further savings. By 1985, the program intends to reduce energy consumption in existing buildings by 20 percent and in new buildings by 45 percent (as compared to 1975 energy use).

By 1990, all Federal buildings with 1,000 or more square feet are planned to be retrofitted with life-cycle, cost-effective energy conservation measures. To meet the 1985 and 1990 goals, Federal agencies are currently preparing long-range 10-year plans.

The Department directs, coordinates, and supports the conservation effort throughout the Government. This past year, for example, the Department published guidelines for a uniform methodology for life-cycle cost analysis and for the development of agency energy conservation plans for buildings and general operations. Based on these guidelines, Federal agencies are preparing to submit 10-year conservation plans. Also, a number of conservation manuals were prepared and distributed to Federal energy managers, and instruction on life-cycle costing, retrofit projects, and operational planning were provided in seminars and workshops.

Next year, the program will complete an overall Federal 10-year conservation plan and be involved in evaluating agencies' conservation plans and performance against those plans. The collection and analysis of energy use data will be a continuing function. Substantial reporting requirements necessitate strong information management and monitoring capabilities; the Department is developing a reporting system to measure Federal progress.

Energy From Municipal Waste

Introduction

The conversion of waste to energy can contribute significantly to the Nation's alternative energy production goals. For example, in 1980, some 156 million tons of municipal solid waste and dry sewage sludge solids were potentially available for energy recovery. The use of all these wastes for energy production could have produced the equivalent of over 200 million barrels of oil. (This figure does not include the 300 trillion Btu of methane that could be extracted from existing landfill sites.) Moreover, should all of the presently unrecovered organic industrial process wastes be converted to energy, the equivalent of an additional 40 million barrels of oil per year would be gained.

In addition to the energy production potential of waste-to-energy, appreciable amounts of energy can be conserved by recycling waste materials and by utilizing more energy-efficient technologies in waste production and wastewater treatment facilities. Current estimates indicate that the energy equivalent of about 75 million barrels of oil could be conserved annually by recycling, while nearly 9 million barrels of oil equivalent could be conserved annually by establishing more energy-efficient wastewater treatment facilities.

Experience has shown, however, that most waste-to-energy projects face major impediments and delays as they

move through the various implementation phases toward start-up and operation, that serious economic problems remain, and that much R&D on promising technologies remains to be carried out. In the light of this experience, it became apparent that a more vigorous Federal program was in order.

In June 1980, the Congress passed and the President signed into law the Energy Security Act (ESA) of 1980 (P.L. 96-294). With this act, the development of energy from municipal waste became a national priority. ESA authorized the Secretary of Energy to provide price support loans, loan guarantees, price guarantees, and construction loans to accelerate the production of energy from municipal waste within economic and environmental bounds. On September 11, 1980, the Secretary established the Office of Energy from Municipal Waste to implement financial incentives and accelerate RD&D programs promoting the commercial viability of waste-to-energy processes.

Financial incentives encourage the sponsorship and financing of waste-to-energy projects. They also support commercial-scale systems that may not be implemented without them, or are being implemented at a slower than desired pace because of generally cautious partners and poor first-cost versus life-cycle economics. RD&D supports innovative technology projects that would not be undertaken without Federal support.

Current Appropriation

The Office of Energy from Municipal Waste currently has \$230.9 million available to implement the Energy from Municipal Waste Program. Of this sum, \$200 million will be used as financial incentives to accelerate the energy from municipal waste industry; \$10.9 million will be used for research and development; and \$20 million will be used to demonstrate near-term technologies.

Program Goals and Strategies

The program has set out to attain four goals. The first is to conserve or produce from 100,000 to 200,000 barrels of oil equivalent per day by 1987; the second, to reach 250,000 to 280,000 barrels of oil equivalent per day by 1992. The first of these goals translates into between 20 and 40 percent of the 1987 synfuels goal; the second, into 12 to 14 percent of 1992 synfuels goals. Clearly, then, municipal waste will play a significant early role in attaining synfuels goals. This is because larger resources such as coal and oil shale take longer to develop.

A third program goal is to integrate energy and materials recovery systems. The removal of inorganics for recycling enhances the operation and efficiency of most energy production facilities, and recycling itself displaces signif-

Figure 2-7

ANFLOW system used to treat waste waters containing toxic heavy materials being evaluated at Oak Ridge National Laboratory

icant quantities of energy. And a fourth goal is to develop more energy-efficient waste water treatment processes.

DOE's program strategy is designed to respond to the needs of the non-Federal partners in the Nation's waste-to-energy initiative, conform to congressional guidance, and maximize the cost-effectiveness of Federal outlays. It is a strategy encompassing as broad a range of technologies, sizes, and settings as possible. And, it includes both private and public sponsors.

The key elements of the strategy are to:

1. Provide financial incentives for accelerated project development.
2. Maximize the productivity of existing waste-to-energy plan development.
3. Reduce the difficulties of financing pre-construction project implementation activities.
4. Demonstrate technologies with high commercial potential.

5. Accelerate research and development.

6. Wherever possible, encourage and supplement the recovery and reuse of energy-intensive materials.

The Department intends soon to issue the mandated financial incentives rules, provide such incentives as loan guarantees, price support loans, and cooperative agreements, and submit to Congress a comprehensive assessment of resource recovery barriers. R&D in the near term will focus on biological systems, rotary screens and other thermal or mechanical resource recovery systems, and the construction of a small-scale removal systems plant.

During 1980, approximately 90 RD&D projects were initiated or in progress. For example, construction was started on a 50,000 gallon per day ANFLOW wastewater treatment demonstration plant in Knoxville, Tennessee. The plant will have an energy-conserving wastewater treatment system based on a fixed film anaerobic bioreactor. The ANFLOW wastewater treatment process has been proven

Figure 2-8—Facility to convert animal waste into methane gas

technically feasible in a 2-year pilot plant project in Oak Ridge, Tennessee. Experiments indicate a possible 75 percent energy savings in small-scale treatment facilities that produce methane-rich gas and meet secondary-level effluent standards. ANFLOW, whose name is derived from anaerobic, upflow, packed-bed bioreactor, is depicted in Figure 2-7. Produced methane gas is being evaluated at the Oak Ridge National Laboratory.

A 50 to 100 ton-per-day facility for producing methane from mixed municipal waste and sewage sludge was commissioned and began operating during the year at baseline conditions. Located at Pompano Beach, Florida, the plant is currently undergoing start-up testing and is producing methane at a rate of 3 million cubic feet per year. When operating at full capacity, it is expected to produce almost 300 million cubic feet per year.

Another facility that converts animal waste into methane gas is shown in Figure 2-8. The conversion process technically known as anaerobic fermentation, uses bacteria to break down cow manure from 10,000 head of

cattle into methane. This facility provides 99 percent of processing plant energy needs, producing steam from cleanup, heating and hot water and replacing most of the 6,250 gallons of fuel oil used per week in the operation.

Recent Activities and Future Plans

During 1980, this program changed from being a branch office with an important but relatively small program, to a full office with a mission of national priority. A comprehensive plan was prepared to guide the development and operation of the newly formed office. The document describing the plan fulfills the requirements of Section 231(c) of the Energy Security Act and sets forth the RD&D and commercialization objectives to be achieved, the management structure, the program strategies, the total estimated construction costs of proposed projects, and the estimated relative financial contributions of the Federal government and nonfederal participants in the program.

During the year, the program also initiated compliance with the Energy Security Act by publishing the following rules in the Federal Register:

1. ESA, Section 233, 235, 236 Guaranteed Construction Loans: proposed and final rules for processing applications for loan guarantees.
2. ESA, Section 234, 235, 236 Price Support Loans: rules setting forth the formula for determining the maximum amount of a price support loan and the procedures in processing applications for price support loans.

State and Local Assistance

Introduction

State and local governments occupy a strategic position in both the total energy picture and the pursuit of conservation. Endowed with an understanding of local energy demand requirements and supply options, they can develop

programs that maximize energy-efficiency improvements and minimize potentially adverse economic or environmental consequences. Because of their unique authority, they can also enact energy conservation laws regulating the utilities, building practices, and land use. Furthermore, states can serve as collection and dissemination points for conservation information of benefit to other states, other regions, or the country as a whole. And while focusing on their own energy concerns, both state and local governments can and do develop approaches that can be used elsewhere.

In the past, the Department's state and local assistance programs operated relatively independently, which limited cross-program comparisons and major revisions to improve program effectiveness, efficiency, and innovations. More recently, these programs began to work together more closely, but the process remained informal. In September 1980, the Office of State and Local Assistance Programs was established to complete the trend away from piecemeal grant-making functions toward a coordinated operation and organization. The purpose of this new office

Figure 2-9

Typical Energy Extension Service activity. Here, homemaker is being advised in proper use and application of insulating materials for maximum energy conservation

to manage and guide a comprehensive approach to conservation and the use of renewable resource technologies at the state and local levels.

As a priority goal, the office will assess the potential benefit of its programs and carry out appropriate changes. The programs expected to be of principal interest include:

1. Programs focused on comprehensive energy conservation planning, including contingency planning affecting a wide range of energy-using sectors (e.g., building, industry, transportation) within discrete governmental jurisdictions.
2. Programs to develop the capacity of state and local governments to cope with the energy management requirements in their jurisdictions.
3. Programs aimed at improving the energy efficiency of schools, hospitals, municipal buildings, and public care facilities.
4. Programs to weatherize the homes of low-income persons and maintain their quality of life by reducing energy expenditures.
5. Emergency conservation programs.
6. Programs to provide direct and personalized technical assistance and information to encourage more effective conservation.

The rationale for all of these programs is that they implement energy conservation in public and non-profit facilities, residences, and commercial establishments where such measures would not otherwise be undertaken.

Energy Extension Service

A Federal/state partnership, the Energy Extension Service (EES) provides energy information and technical assistance to small-scale energy users. Through local organizations and other qualified delivery mechanisms, this program focuses on informing small business and individual energy consumers about self-help projects that save energy. The states have the flexibility to design useful conservation services that are then delivered by existing organizations. A typical EES activity is viewed in Figure 2-9, where a homeowner is being advised how to apply insulation material for maximum benefit in energy conservation.

As mandated by the National Energy Extension Service Act of 1977, Title V of Public Law 95-39, the program began with a pilot effort involving ten states¹ in August 1977. The national program was to have been launched in October 1978. A stipulation of the 1979 EES appropriation, however, required that an evaluation report on the pilot program be submitted to the appropriate congressional appropriations committees prior to implementation of the

nationwide EES program. The required report was submitted to the Congress in March 1979, and congressional approval for nationwide expansion was received in July 1979.

Under the pilot program, the principal beneficiaries were residential energy users, small businesses, local governments, and other public institutions. Some of the energy conservation projects that have emerged include: an information clearinghouse and hotline in Michigan; self-help solar workshops in New Mexico; a boiler and water heater efficiency program for commercial businesses in Alabama; city and county energy management in Tennessee; home energy audits in Wyoming; and home builders workshops in Texas.

Table 2-1 lists grants awarded to states in 1980.

Table 2-1. — Energy extension service, 1980

State	Funds	State	Funds
Alabama	474,200	Missouri	557,000
Alaska	263,300	Montana	289,600
American Samoa	244,800	Nebraska	342,700
Arizona	362,100	Nevada	275,800
Arkansas	372,100	New Hampshire	292,500
California	1,583,700	New Jersey	724,000
Colorado	391,400	New Mexico	311,300
Connecticut	446,500	New York	1,467,600
Delaware	279,800	North Carolina	584,300
District of Columbia	293,800	North Dakota	284,500
Florida	698,900	Ohio	958,400
Georgia	551,000	Oklahoma	414,800
Guam	248,700	Oregon	383,400
Hawaii	294,700	Pennsylvania	1,035,200
Idaho	290,800	Puerto Rico	425,100
Illinois	988,900	Rhode Island	306,800
Indiana	591,800	South Carolina	416,900
Iowa	432,600	South Dakota	287,700
Kansas	394,000	Tennessee	506,600
Kentucky	459,200	Texas	994,800
Louisiana	487,700	Trust Territory	249,800
Maine	309,700	Utah	314,100
Mariana District	243,800	Vermont	272,900
Maryland	506,400	Virginia	555,200
Massachusetts	624,900	Virgin Islands	247,100
Michigan	839,300	Washington	472,100
Minnesota	498,500	West Virginia	360,100
Mississippi	391,800	Wisconsin	539,600
		Wyoming	265,300

State Energy Conservation Program

Established in December 1975 under the Energy Policy and Conservation Act, and amended by the Energy Conservation and Production Act of 1976, this program requires that each participating state and territory develop a comprehensive energy conservation plan. The plan must

¹ Alabama, Connecticut, Michigan, New Mexico, Pennsylvania, Tennessee, Texas, Washington, Wisconsin, and Wyoming.

include: mandatory lighting efficiency standards for public buildings; programs to promote the availability and use of carpools, vanpools, and public transportation; mandatory energy efficiency standards and policies relating to state procurement practices; mandatory thermal efficiency standards and insulation requirements for new and renovated buildings; and right-turn-on-red traffic laws or regulations. The plan may also include a broad range of other innovative measures.

In 1980, the program target was to reduce projected energy consumption in participating states by at least 5 percent. The states expect to realize approximately 30 percent of their energy savings from required measures. They expect to achieve 70 percent of their 1980 energy savings goal by means of such innovative programs as energy efficiency demonstrations and training for Kansas farmers, beverage container regulations in Iowa, utility-supported one-stop audit and insulation service in Rhode Island, legislation encouraging the use of solar energy as a substitute for additional energy sources, and transportation planning

manuals used in developing new communities in Oregon.

In addition to financial assistance, DOE provides technical assistance and information to the states. This assistance includes computerized information retrieval systems, educational materials ranging from posters to complex technical reports, training seminars and workshops, on-site technical expertise (on the specific request of a state), and coordination and liaison that includes exchanging program information and technical expertise and making specific state capabilities available to other states.

Table 2-2 lists grants awarded in 1980 by region and by state.

During the past year, the states made significant progress toward increasing energy conservation through such activities as adopting statewide lighting energy efficiency standards for new public buildings in 42 states and for existing public buildings in 19 states. Thermal energy efficiency standards for new buildings have also been adopted in 38 states. Seven of the states have adopted thermal efficiency standards on less than a statewide basis, while six of

Figure 2-10—Home insulation and weatherization workshop

*he states have adopted standards only for state-owned uildings.

Institutional Conservation Program

The grants programs for schools, hospitals, local governments, and public care institutions were established by the National Energy Conservation Policy Act (P.L. 95-619), to provide 50/50 matching Federal grants for assistance in identifying energy conservation opportunities in such buildings and implementing energy conservation measures in schools and hospitals.

These programs provide support for several activities. Preliminary energy audits gather information about eligible buildings such as hours of operation, energy use patterns and costs, size, types of windows, and equipment. Energy audits go further, requiring an on-site review to determine potential energy-conserving changes in operating and maintenance procedures. Technical assistance provides detailed engineering analyses and reports specific costs, payback periods, and projected energy savings expected from the purchase of devices, or the modification of building envelopes. Only schools and hospitals are eligible for financial assistance needed to implement measures recommended by the technical assistance analyst.

Preliminary energy audit and energy audit grants are made to states. Grants for technical assistance and conservation measures are awarded by the Department directly to eligible institutions in accordance with Federal regulations and state-wide plans developed by each state energy office. Funds granted to a state, local government, or individual institution must generally be matched 50/50 with non-Federal funds. Grantees may use in-kind contributions to make up all or part of this match. To date, more than 7,500 institutions have received a total of more than \$200 million. In 1980, 11,725 schools and hospitals received technical assistance, and 6,015 schools and hospitals received funds for undertaking conservation measures. Also, 2,844 local government and public care institutions were provided with technical assistance.

Weatherization Assistance Program

Title IV Part A of the Energy Conservation and Production Act of 1976 (P.L. 94-385) established a Weatherization Assistance Program to achieve a "level of insulation in the dwellings of low-income persons, particularly elderly and handicapped low-income persons, in order both to aid those persons least able to afford higher utility costs and to conserve energy." The Department administers the program through its ten regional offices, which review grant applications and state plans, make grant awards, and monitor state programs. Originally, grants were made to the states according to a formula

based on low-income population, number of heating and cooling degree days, and weatherization work to be done. Program regulations were revised in February 1980, introducing the concept of performance funding into the award process.

Figure 2-10 illustrates a typical home insulation and weatherization workshop conducted under the Weatherization Assistance Program.

Table 2-2 — 1980 state allotments by region

<i>Region</i>	<i>Base</i>	<i>Supplemental</i>	<i>Total</i>
(dollars)			
<i>Region I</i>			
Connecticut	\$ 480,300	\$ 150,000	\$ 630,800
Maine	284,800	80,700	365,500
Massachusetts	742,300	242,900	935,200
New Hampshire	247,800	72,300	320,100
Rhode Island	294,100	76,000	370,100
Vermont	221,900	60,300	282,200
Total	\$ 2,271,200	\$ 682,700	\$ 2,953,900
<i>Region II</i>			
New Jersey	\$ 1,086,800	\$ 296,100	\$ 1,382,900
New York	2,175,400	664,300	2,839,700
Puerto Rico	423,200	154,000	577,200
Virgin Islands	171,100	47,100	218,200
Total	\$ 3,856,500	\$ 1,161,500	\$ 5,018,000
<i>Region III</i>			
Delaware	\$ 241,000	\$ 63,900	\$ 304,900
District of Columbia	253,700	67,900	321,600
Maryland	616,000	185,600	801,600
Pennsylvania	1,694,000	449,500	2,143,500
Virginia	769,700	217,500	987,200
West Virginia	399,500	106,800	506,300
Total	\$ 3,973,900	\$ 1,091,200	\$ 5,065,100
<i>Region IV</i>			
Alabama	\$ 648,200	\$ 169,400	\$ 817,600
Florida	1,215,900	330,900	1,546,800
Georgia	732,900	215,100	948,000
Kentucky	678,000	161,900	839,900
Mississippi	452,900	125,100	587,000
North Carolina	866,500	231,600	1,098,100
South Carolina	463,100	141,600	604,700
Tennessee	718,700	189,400	908,100
Total	\$ 5,776,200	\$ 1,565,000	\$ 7,341,200
<i>Region V</i>			
Illinois	\$ 1,688,500	\$ 428,500	\$ 2,117,000
Indiana	1,000,100	226,400	1,226,500
Michigan	1,490,800	357,000	1,847,800
Minnesota	725,100	179,700	904,800
Ohio	1,482,500	411,200	1,893,700

Wisconsin	821,500	202,300	1,014,800
Total	\$ 7,199,500	\$ 1,805,100	\$ 9,004,600

Region VI

Arkansas	\$ 550,000	\$ 116,600	\$ 666,600
Louisiana	944,600	177,000	1,121,600
New Mexico	319,800	84,100	403,900
Oklahoma	568,600	139,100	707,700
Texas	2,240,800	476,800	2,717,600
Total	\$ 4,623,800	\$ 999,000	\$ 5,617,400

Region VII

Iowa	\$ 562,600	\$ 142,600	\$ 705,200
Kansas	540,000	122,900	662,900
Missouri	686,900	208,400	895,300
Nebraska	362,900	97,200	460,100
Total	\$ 2,152,400	\$ 571,100	\$ 2,723,500

Region VIII

Colorado	\$ 458,300	\$ 132,400	\$ 590,700
Montana	253,000	69,800	322,800
North Dakota	299,000	66,000	295,000
South Dakota	234,000	67,400	301,400
Utah	319,600	86,200	405,800
Wyoming	237,100	57,300	294,400
Total	\$ 1,731,000	\$ 479,100	\$ 2,210,100

Region IX

American Samoa	\$ 164,600	\$ 44,900	\$ 209,500
Arizona	419,800	121,200	541,000
California	2,380,200	783,500	3,163,700
Guam	169,700	47,200	216,900
Hawaii	247,100	74,200	321,300
Nevada	163,600	64,900	313,000
N. Mariana Is.	163,600	44,400	208,000
Trust Territory	170,800	48,200	219,000
Total	\$ 3,963,900	\$ 1,228,500	\$ 5,192,400

Region X

Alaska	\$ 229,500	\$ 57,900	\$ 287,400
Idaho	260,700	72,500	333,200
Oregon	487,300	123,800	611,100
Washington	474,100	168,000	642,100
Total	\$ 1,451,600	\$ 422,200	\$ 1,873,800

Grand total	\$37,000,000	\$10,000,000	\$47,000,000
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DOE estimates that 310,000 homes will be weatherized in 1981. This compares to 265,000 houses weatherized in 1980. Each weatherized home will account for savings of 2.5 barrels of oil per year. In order to attain this goal, the Department will tentatively award initial funds to states to carry out their 1981 programs, evaluate the programs, and reallocate 1981 grant funds in the spring based on performance. Personnel expect to work with the Residential Conservation Service in developing standards, searching for

new types of weatherization materials, and reviewing the "comfort zones" concept for suitability to the program. Program managers expect improvements in state program management from the use of a *State Program Manual*, audit guidelines, and training modules on financial management, reporting and evaluation systems, contract administration, and weatherization skills training.

Inventions and Small-Scale Technology

The Office of Inventions and Small Scale Technology was established to complement the long-term, centralized approach to a national conservation program. Its mission is to encourage, through the provision of financial and other assistance, the development and diffusion of energy-related inventions and small-scale appropriate technologies in order to realize energy savings in the shortest time possible. This goal is pursued through two programs: the Energy Related Inventions Program and the Appropriate Technology Small Grants Program.

Energy-Related Inventions Program

It is a documented fact that individual inventors and small businesses provide more new ideas and create more new jobs than do large firms. Small firms are risk-oriented and their work often provides large technological breakthroughs. This program identifies inventions that are ready to be moved into the private sector but may require business management assistance, further R&D prototype fabrication, or laboratory tests. The program provides one-time assistance (usually in the form of grants) to selected inventors to develop their ideas for eventual commercialization.

To date, the Department has awarded 83 grants and contracts amounting to \$5.45 million. Approximately 22 grants, valued at approximately \$1.34 million, were awarded in 1980. Applications have been received from inventors in every state and U.S. territory.

Among the most recent ideas selected for DOE financial assistance are an award-winning, low-cost method of erecting energy-conserving office buildings, a compressor control system for gas transmission pipelines, a solar-powered tobacco curing barn, a low-cost, freeze-proof passive solar collector, an insulating window shade, and a high-efficiency water heater.

Appropriate Technology Small Grants Program

This program provides eligible individuals, small businesses, local nonprofit organizations, state and local agencies, and Native American tribes with grants of up to \$10,000 for concept development, or up to \$50,000 for hardware development or demonstration of small-scale energy technologies appropriate to local needs.

The term "appropriate technology" refers to technology that is most suitably adapted to the conditions of a given situation and is compatible with the human, financial, and material resources that surround its application. Thus, appropriate technology strives to make best use of available renewable energy sources and to conserve nonrenewable resources, depends largely on human labor, and maximizes use of local materials and labor skills.

In scale and efficiency, appropriate technology uses energy and other resources efficiently, is simple to install, operate, and maintain, may employ scaled-down industrial technology, and emphasizes decentralized technologies. In relation to the end-user, appropriate technology satisfies local needs, increases community energy understanding and self-reliance, is environmentally sound, and leads to durable recyclable systems and/or products.

In 1980, more than 10,000 grant proposals were submitted. Approximately 850 projects were provided financial assistance from the \$12 million in grant monies available. One example of a funded project is an effort by a high school in Massachusetts to build and install a wind generator to power its FM radio station, demonstrating to its listeners the potential for an economic and geographically suitable energy source. Under another grant, two individuals in Vermont are assembling and testing a variety of steam-generating systems. Their goal is to develop a small-scale, wood-fired steam plant for home electricity generation that would be adaptable for other uses. Another grant will be used to develop a "showcase" laundromat in Los

Angeles that will demonstrate a number of different energy technologies. It will incorporate techniques of waste water heat recovery, insulation of storage tanks and hot water heater, solar hot water heating, and sawtooth roof construction to provide maximum natural lighting.

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Chapter 3

Fossil Energy

Introduction

The United States relies on fossil energy for approximately 85 percent of its energy requirements. Unfortunately, once-plentiful conventional energy supplies cannot be counted on for long-term energy security. The United States is rapidly exhausting its oil and natural gas resources and has become overly dependent on unstable foreign oil supplies. It has become critically important to remove unnecessary obstacles to conventional production of our remaining oil and gas supplies, to spur production of less conventional fossil resources, and to actively develop new technologies and markets for our most abundant domestic fossil resource—coal.

Liquid and gaseous fuels from petroleum and natural gas have long been preferred to coal because they are cleaner to produce and use, are easier to transport and store, and are immediately usable in most existing energy-consuming systems designed to use these energy forms. On the other hand, more energy can be produced from U.S. coal deposits than from the combined domestic resources of petroleum, natural gas, oil shale, and tar sands. The Department of Energy's Office of Fossil Energy is attempting to increase domestic production of all fossil fuels and, considering the vast wealth of coal reserves, is focused on facilitating the development and use of coal.

During 1980, industries and utilities worldwide continued their turn toward coal as a primary energy source. Production topped 825 million tons in 1980, almost 50 million tons over 1979 production. The largest growth in domestic consumption occurred in the electric utility sector. In the first half of 1980, coal accounted for more than half the electricity generated by U.S. powerplants, and consumption was projected to increase beyond 1979 levels by almost 40 million tons.

The sharpest increase in coal demand came from foreign buyers, especially in countries of the European Economic Community, which began seeking U.S. coal as a replacement for imported oil in 1979 when the price of world oil doubled from the previous year. The *Report of the World Coal Study*, a major international report released in May 1980 by contributors from 16 major countries, predicted that coal could provide two-thirds of the added energy needed to fuel the world's economic growth over the next 20 years. Leaders of seven major consuming nations, including the United States, met in Venice in June and agreed to a strategy that would triple world coal production by the year 2000.

With coal reemerging as a prime substitute for expensive oil, President Carter decided in 1980 to accelerate both domestic and international coal production and use. Among the initiatives was a \$10 billion, 10-year program

to provide utilities with financial assistance needed to convert, where possible, powerplants from oil to coal. The President's proposal, announced in February, also encouraged energy conservation in utilities that cannot convert to coal to plan the construction of new powerplants that would use coal or other alternative fuels.

In an effort to increase U.S. participation in world coal trade, the President established an interagency task force to recommend ways of ensuring that American coals could compete in an expanding international market.

The largest undertaking during the year was the establishment of the Synthetic Fuels Corporation. Approved by Congress on June 30, slightly less than a year after President Carter proposed its creation, the Government-sponsored corporation will provide an array of financial incentives potentially totaling an estimated \$20 billion during the next 12 years. The incentives are intended to stimulate construction of commercial plants to convert coal, oil shale, and tar sands—among other resources—into synthetic petroleum and gas.

The Nation's two largest experimental coal-to-liquid pilot plants began operating in 1980. Both facilities are designed as forerunners of improved commercial synthetic fuels plants expected to be ready by the late 1980's.

Development of another advanced synthetic fuel technology also surpassed a key milestone in 1980. In July, President Carter and ambassadors of the Federal Republic of Germany and the Government of Japan signed an international accord to fund the construction and operation of a full-scale plant, currently estimated to cost \$1.4 billion, to demonstrate the Solvent-Refined-Coal liquefaction technology. A week later, Federal officials and representatives of two U.S. industrial firms agreed to share the costs of a second Solvent-Refined-Coal demonstration plant, this one to produce a different slate of products (including clean-burning solid synthetic fuel).

Funding for coal research and development, including both synthetic fuels technologies and techniques for improved coal mining and combustion, increased by more than \$150 million in 1980, and will exceed \$1 billion in 1981.

Alternative Fuels

Congress established the Energy Security Reserve (Department of the Interior and Related Agencies Appropriations Act of 1980, P.L. 96-126) on November 27, 1979, to stimulate the creation of a major synthetic fuels industry. An initial \$2.2 billion was appropriated for use by DOE under the Federal Nonnuclear Research, Development, and Demonstration Act of 1974 to provide support to industry for planning, designing, and constructing alternative fuels projects. This appropriation was intended as

an interim measure to maintain industry momentum, pending creation of the U.S. Synthetic Fuels Corporation. Of the \$2.2 billion, Congress allocated \$100 million for project feasibility studies, \$100 million for cooperative agreements to complete final designs or to initiate construction of projects that are beyond the feasibility stage, \$500 million for a loan guarantee reserve, and \$1.5 billion for purchase commitments and price supports. The synthetic fuels projects eligible for support were those producing fuels or chemical feedstocks that could be substituted for petroleum or natural gas, except by direct combustion, and that were derived from coal, oil shale, tar sands, biomass, or municipal waste.

Additional synfuels-related legislation was enacted during 1980. The Energy Security Act, P.L. 96-294 was enacted July 1, 1980. Title I, Part A of this act amended the Defense Production Act of 1950 to authorize financial assistance under the Defense Production Act for synthetic fuels projects to meet defense needs. Shortly thereafter, a supplemental appropriation (P.L. 96-304) of \$3.3 billion to the DOE Energy Security Reserve was enacted. Of this, \$300 million was provided for a second round of feasibility studies and cooperative agreements, and \$3 billion was provided for additional purchase agreements and price and loan guarantees. The \$3 billion was authorized under Defense Production Act amendments. This assistance was limited to synthetic fuels produced from coal, oil shale, tar sands, certain heavy oils, and water (as a source of hydrogen). Coal-oil mixtures were included, but biomass and municipal wastes were excluded from this part of the Energy Security Act.

Title I, Part B of the Energy Security Act (the United States Synthetic Fuels Corporation Act of 1980) created the U.S. Synthetic Fuels Corporation to serve as the principal entity for providing financial assistance to create a major synthetic fuels industry. The act establishes a national goal of achieving a synthetic fuels production capability from domestic resources equivalent to 500,000 barrels of oil per day by 1987, and 2 million barrels per day by 1992. A wide range of financing devices—price guarantees, Federal purchase agreements, direct loans, and loan guarantees—will be made available by the Corporation to achieve maximum leverage within the private sector.

In October 1980, House Joint Resolution 610, Making Continuing Appropriations for 1981, contained some modifications of the interim program established by the appropriation acts P.L. 96-304 and P.L. 96-126. The definition of tar sands was expanded to include heavy oils in a manner similar to that in the Energy Security Act. Obligations of up to \$30 million were authorized in the feasibility studies and cooperative agreements programs for direct combustion technologies (excluding municipal wastes). Of the \$1.5 billion originally appropriated for

purchase commitments and price guarantees in P.L. 96-126, up to \$500 million may be used instead for loan guarantees, bringing the authorized loan guarantee reserve up to a maximum of \$1 billion, and the amount of potential loan guarantees up to a maximum of \$3 billion.

The alternative fuels interim program proceeded on schedule during 1980. The first round of solicitations for feasibility studies and cooperative agreements was issued on February 25, 90 days after the enactment of P.L. 96-126. A total of 971 proposals was received. On July 9, DOE announced the selection of 110 proposals for negotiation of the award of grants and cooperative agreements aggregating approximately \$200 million. Of those selected, 99 were for feasibility studies and 11 for cooperative agreements. The evaluations were conducted by special DOE teams, including about 200 experts from the many technologies involved. A wide variety of technologies, resources, and geographical locations were selected in accordance with the intent of the Administration and Congress.

The second round of similar solicitations was issued shortly after the enactment of P.L. 96-304. Announcement of awards totaling \$270 million was scheduled for mid-December. A separate solicitation for direct combustion awards in the amount of \$30 million was issued as required in House Joint Resolution 610.

Draft solicitations for price guarantees, purchase commitments, and loan guarantees were released for public comment on August 26, as a joint effort of the Department of Energy and the Department of Defense. Two solicitations were issued guarantees, one for price loan guarantees and purchase agreements (Department of Energy), and one for purchase agreements and loan guarantees for synfuels plants to produce synfuels for defense use (Department of Defense).

Evaluation of the price guarantee, purchase agreement, and loan guarantee proposals was carried out by a joint Department of Energy/Department of Defense task force. Announcement of the awards is tentatively scheduled for 1981. It is anticipated that when the Synthetic Fuels Corporation is declared operational, it will assume responsibility for managing the agreements awarded. It is also expected that the Department of Energy will assist the Synthetic Fuels Corporation by providing advisory services and technological, economic, or environmental assessments, as requested.

Coal Resource Management and Supply Development

To allow the Nation to realize the full potential of its vast coal resources, the Department of Energy is working to accelerate the acceptance of direct combustion and syn-

thetic fuels technologies.

Though some synthetic fuels processes are technically ready for commercialization, private industry has not made the substantial investments (\$2 billion to \$4 billion per plant) necessary for commercial production in this country. Concerns about economics, suitable site locations, environmental requirements, and markets for products impede commercialization of gasification and liquefaction technologies. Through the Office of Coal Resource Management, the Department is assisting the commercialization of coal synthetic processes that have the greatest potential for displacing imported oil.

Assistance is offered in such areas as permitting and licensing, streamlining regulatory processes at all levels of government, and Environmental Impact Statement preparation. Once a plant begins production, its operations will be analyzed to determine useful data and experience applicable to future coal-burning plants. The objective is to attract additional companies to build and operate synthetic fuel plants.

The introduction of new, commercially ready technologies for direct combustion of coal will follow essentially the same path as that described for synthetic fuels. The first plants will be encouraged with funding assistance and assistance in regulatory matters. A major effort continues in assisting the voluntary conversion of oil- and gas-burning installations to coal-based fuels. Combustion technologies currently available include atmospheric fluidized-bed combustion, integrated coal gasifier combined-cycle, and coal-oil mixtures. The Office of Coal Resource Management is providing assistance in resolving barriers to utility and industrial conversion, including financial, environmental, and institutional problems.

Along with Coal Resource Management, the Office of Coal Systems provides guidance for the development of coal synthetics and direct combustion. Since the needs of coal-burning facilities vary with the synthetic process and their industrial use, the office defines and analyzes specific problems with various types of coal systems. Many aspects of coal utilization are monitored and evaluated, such as coal availability by type and location, transportation costs, coal preparation and handling equipment, and ash or sludge removal requirements. Combined with the financial incentives provided in the loan guarantee program, technical assistance from the Department should increase the number of coal conversion facilities.

Federal Coal Leasing

The Department of Energy monitors coal and coal synfuels production goals to ensure that the Department of the Interior will offer adequate coal reserves for lease to meet the growing domestic and export coal demand. DOE

currently approves coal lease terms and conditions to foster competition and enhance production. National coal production goals are published to help ensure that the coal leasing program is responsive to changing market conditions and national energy needs.

Delays in coal leasing have stemmed in part from the requirement to consider the social, economic, and environmental consequences of energy development. The Department of Energy has recommended that the Department of the Interior lease sufficient additional acreage over the next 2 to 3 years to make available up to 8 billion tons of coal. The national coal production goal for the medium demand scenario is 1.37 billion tons in 1990 and 1.72 billion tons in 1995. These goals represent a doubling of coal production from 1978 to 1990.

Licensing and Siting

The licensing and siting program seeks to alleviate constraints on coal-producing and coal-consuming energy facilities by lessening permitting, licensing, and siting impediments and by reducing by 10 percent the time required to obtain permits affecting their development. This is being achieved in part by coordinating Federal siting and licensing programs with state and local procedures and in part by streamlining the siting/regulatory processes for coal-fired energy facilities. Also, siting barriers and monitoring facilities are identified through the licensing and siting process. In a related effort, DOE is continuing to participate in the Office of Management and Budget Task Force, which provides a computerized tracking system for monitoring the status of coal facilities.

The Licensing and Siting Program office continues to publish the *Inventory of Power Plants in the United States* in conjunction with the Energy Information Administration. The office tracks the status of all projected powerplants and provides the information to EIA. Data listings identify the responsible Federal agencies, along with the address and telephone number of persons responsible for permit/license approval. In addition, information is provided to the White House's Energy Coordinating Committee on specific licensing and siting delays that may be resolved.

Coal Loan Guarantees

Under authority of the Energy Policy and Conservation Act of 1975, the Department of Energy may provide financial incentives to small- and medium-sized coal producers to develop, expand, or reopen underground low-sulfur coal mines. This act, expanded by the Power Plant and Industrial Fuel Use Act of 1978, provides loan guarantee authority for coal preparation plants designed to reduce the sulfur content of coal.

The Department may issue up to \$750 million in loan guarantees for projects complying with all environmental and safety regulations. Each project must also be financially sound, as defined by the statute and the program's regulations. The maximum loan guarantee is 80 percent of any loan, and the limit for each borrower is \$30 million. Introducing the assistance program to the coal industry and commercial banks, DOE approved conditional commitments for loan guarantees totaling \$6.7 million in 1981.

Anthracite

Although anthracite is the most desirable type of coal for residential and commercial heating, its production has declined almost 90 percent since 1945 and now accounts for only 1 percent of all coal mined in the United States. Production has been limited by difficult geologic conditions, environmental constraints, and labor-intensive low production rates that make anthracite more expensive to mine than bituminous coal.

The Department of Energy is working on measures to revitalize the anthracite industry in the Northeast, where most of the reserves are located. Part of the strategy is to provide technical and related information and guidance, as well as policy recommendations. Through a combination of public awareness programs and field projects, DOE hopes to improve the prospects for the anthracite industry.

In addition, the Department plans to undertake a comprehensive study in 1981 of the potential for using anthracite for alternative fuels production. Among the technologies to be studied are chemical feedstock production, atmospheric fluidized-bed combustion using anthracite culm, anthracite coal-oil mixtures, and the use of anthracite for cogeneration.

High-Btu Gas

The high-Btu gas commercialization program proposes to have two or three high-Btu coal gasification projects in operation by the mid-1980's as the Nation attempts to reach the synthetic fuels production goal of 2 million barrels of oil equivalent per day by 1992.

The Department of Energy continues to support the Great Plains Gasification Associates in constructing a pioneer large-scale, high-Btu gas commercialization project in Mercer County, North Dakota. Through a cooperative agreement, \$25 million was provided for preconstruction engineering and detailed design activities. These funds are to be repaid upon successful financing of the project. In March 1980, four parties petitioned the District of Columbia, U.S. Court of Appeals for reconsideration of the Federal Energy Regulatory Commission (FERC) Order on the Great Plains project. Final financing arrangements and construction activities were delayed because of the

issues raised by these appeals, and the court has ruled that "ERC exceeded its authority in issuing the order. Thus, the great Plains Gasification Associates is reexamining its financial alternatives.

Also during the year, program officials managed the evaluation of high-Btu gas feasibility studies and cooperative agreement proposals submitted in response to the February 1980 P.L. 96-126 solicitations. Two projects were selected for a cooperative agreement award. DOE is now providing financial support to four commercial high-Btu gas projects and expects to have two or three high-Btu gas projects in operation by the mid-1980's.

Low- to Medium-Btu Gas

Currently, the Department's objectives are to reduce barriers to commercialization of the technology for deriving low- to medium-Btu gas through coal gasification. Plans are to establish 10 to 20 coal gasification plants in the period from 1984 to 1986 in each of three specific application areas—single user, district gas, and power generation. Experience gained from current feasibility studies and incentives from P.L. 96-126 and P.L. 96-304 should lead to the operation of large gasification plants.

During 1980, 14 feasibility studies were funded under a Notice of Program Interest. These projects involved 12 states and covered a wide range of financing and applications issues. Seven additional feasibility studies that represented all areas of application were awarded under the solicitation based on P.L. 96-126. The Department's share of the cost will be about \$17 million. In addition, contracts have been awarded for studies to assess foreign gasification technology and to provide state regulatory information to develop specific industrialization plans.

Two reports on low- to medium-Btu gasification were published during the year. One was a widely distributed market study that indicated a large market for low- to medium-Btu gasification. The other publication was a regulatory/siting case study for a number of low-Btu projects in various stages of design, construction, and operation. Future plans include publication of an analysis of the initial 14 feasibility studies and completion of planning for a 1982 workshop.

The Interagency Coal Export Task Force

In April 1980, the President created the Interagency Coal Export Task Force to report on the Nation's potential for increasing coal exports in a manner consistent with other national policies (including the commitment to environmental protection). Sixty members from thirteen agencies make up the Task Force, which is charged with setting targets for increasing steam coal sales abroad and with making recommendations on how to overcome in-

stitutional constraints that hinder the attainment of such sales.

In carrying out its mandate, the Coal Export Task Force is searching for ways to help the coal industry in the areas of supply and demand, port facilities and ocean transportation, inland transportation, marketing and related business issues, international cooperation, and environmental impact.

In May 1980, participants in the World Coal Study predicted a resurgence in international coal trade and projected that U.S. exports could reach 70 to 80 million tons in 1985, 85 to 125 million tons in 1990, and 125 to 200 million tons by the year 2000. The objective of the Interagency Coal Export Task Force is to boost exports beyond these levels. If 100 million tons of coal were exported at \$50 per ton, the sale could earn \$5 billion a year, which would contribute to a positive U.S. balance of trade.

As a result of higher oil prices and uncertainties of supplies from the volatile Middle East, international coal buying has already surpassed the expectations of most energy analysts. In the fall of 1980, based on reports of coal carrier traffic at the Nation's largest coal port (Hampton Roads, Virginia), it became evident that the projections for 1985 export levels could be reached by the end of 1980. This increased demand has created a pressing need at all U.S. ports for two expensive features: deeper channels to accommodate deep-draft coal colliers and ground facilities equipped to handle coal faster.

Based on preliminary work by the Task Force, the Department of Energy announced plans in October for 1981 legislation to provide the President with generic authority for deepening channels and other port improvements. Designed to improve the Nation's competitive position in the world market, the legislation would replace the current port-by-port congressional authorization process with a streamlined approach. This would eliminate up to 2 years of the time otherwise required.

President Carter also directed the U.S. Army to take all possible steps to shorten the review of current proposals to dredge U.S. ports. Even if no generic authorization legislation is passed, proposals made by the Army in response to the President's request could shorten by 3 to 4 years the time necessary to modernize coal exporting facilities at many U.S. ports.

Coal Research, Development, and Demonstration

New technologies will be critical in the Nation's shift toward more abundant fossil fuel resources such as coal. While techniques exist today for using coal in an environmentally acceptable manner, improvements will permit a wider range of coals to be burned or converted to synthetic fuels more efficiently with even greater en-

vironmental attractiveness. Also, new techniques can increase the efficiency of mining coal and the effectiveness of preparing it for eventual use.

Virtually all coal produced in the United States today is burned by the utility and industrial sectors, and it is likely that direct burning will be the principal means of using coal during the remainder of this century. Consequently, DOE's Fossil Energy program is focusing on new technologies to allow more coal to be burned cleanly and efficiently in the near term. Programs are under way to improve today's methods of cleaning the flue gas of coal combustion and to develop new combustion techniques such as the fluidized-bed coal burning system.

Concurrent with the development of new coal burning technologies is a major effort to develop improved processes for converting coal into clean-burning synthetic liquids, gases, and solids. When ready for commercial use, these new synthetic fuels techniques are expected to have significantly improved efficiencies, environmental performance, and flexibility in using a much wider variety of coals.

Improving the efficiency of producing energy is a major objective in the development of advanced coal-using technologies, such as the fuel cell, the magnetohydrodynamic power system, and the technique for integrating a coal gasifier with both gas and steam turbines in a combined-cycle operation.

Spanning the entire coal technology program is an advanced and exploratory research effort to study the fundamental phenomena of coal combustion and utilization as well as to develop improved materials for use in advanced coal facilities.

Mining Research and Development

The Department of Energy's coal mining program is aimed at improving production economics and maximizing resource recovery while protecting the health and safety of mine workers and the environment.

Production delays in underground mining are often associated with activities necessary to secure mine roof supports. A new technique that was successfully tested in the spring of this year promises to help alleviate this problem. Working under a DOE contract, a company designed a piece of automated equipment to speed the roof bolting process and make it possible to secure roof bolts greater than the height of the coal seam. This capability is particularly valuable for thin-seam (3 to 5 feet) mining, where increasingly greater coal production must occur.

Another delay occurs while the roof bolts are installed or coal extraction equipment is positioned. During the preparation time, mining machines often sit idle for up to 75 percent of a shift. Work began in 1975 to develop a single machine that would integrate roof bolting with the

actual mining of coal, and initial field tests have been conducted using different design concepts. Based on these early tests, modifications were made to some of the design for these continuous miner/bolters, and preparations were begun for new laboratory and field tests in 1981.

To take advantage of the full production potential of miner/bolters, methods for continuously hauling coal from the mining area are needed to replace the intermittent haulage by shuttle cars typically used today. Production could be increased by almost 45 percent solely by using a continuous haulage system. During 1980, a successful series of surface trials for such a system was completed at DOE's Pittsburgh Mining Technology Center. Called an auto track bridge, this conveyor operates by following a unique flexible cable from the mine face to an underground transfer point. When complete, the multi-unit train will be 500 feet long.

Yet another deterrent to coal production is the time consumed in accessing in-mine roadways to the coal seam to provide conduits for ventilation as well as passages for miners and materials needed to set up production sections. Representing the United States in England, DOE recently helped sponsor a series of successful, internationally funded tests of a prototype machine designed to speed the process of driving tunnels to coal seams. This machine uses high-pressure water jets to assist the cutting action of mechanical pick-type rock cutters. The water jets are capable of exerting a force of 8,000 to 10,000 pounds per square inch and serve to reduce respirable dust, decrease the hazard of explosions, and allow the cutting of previously impermeable strata.

Surface mining continues to provide an increasingly greater percentage of the Nation's coal production. This trend should continue because surface mining production costs are less than underground mining costs, and surface mining has the added advantages of greater resource recovery rates and fewer miner health and safety problems. Like underground mining, surface mining has production limitations that the Department of Energy is currently working to improve. Among the new equipment being developed is a low wall conveyor system that was tested during the summer at a mine outside Hazard, Kentucky. Designed to decrease operating costs, the system will replace trucks now used in contour mining for moving soil overlying a coal seam around the mountainside to a trailing spoil pile. Beginning in 1981, new ancillary equipment will be added, and modifications will be made to equipment to increase reliability. Another series of tests will then be conducted at a different mine site.

Coal preparation is yet another aspect of the coal mining process to be considered. After it leaves the mine, almost all coal is at least partially cleansed of as many impurities (sulfur, ash, and trace elements) as possible. As more continuous mining—which introduces large--

amounts of impurities into the raw coal feed—is done, coal preparation techniques become increasingly important. During the year, DOE demonstrated an advanced process for cleaning coal that removed 89 percent of the sulfur and 94 percent of the ash from Kentucky Number 11 coal. Like most of DOE's mining research and development, this technique, which involves caustic leaching of washed coal, is being developed in conjunction with private industry. Additional tests will be conducted at a firm's Southern California development center in an effort to reduce processing costs.

Coal Synthetics Research and Development

With technologies for converting coal into liquids and gases available today, private firms are preparing to construct the first commercial plants using incentives provided by the Department's Alternative Fuels program (page 3-2). Concurrently with this program, the Department of Energy continued its development of more advanced generations of synthetic fuel processes. These new techniques are particularly attractive because they offer potentially large gains in efficiency, environmental performance, and the capability of using a wider range of coals.

On May 29, the Department's H-Coal liquefaction pilot plant near Catlettsburg, Kentucky, produced its first

synthetic oil from coal. This milestone, following more than 3 years of construction, propelled the Nation's coal liquefaction research program from small-scale testing into large-scale engineering development.

The H-Coal plant can process from 200 to 600 tons of coal per day, producing either a synthetic crude oil suitable for refining or a heavier, low-sulfur fuel oil. The process was developed by private industry, under a contract with the Department of Energy, to which the Commonwealth of Kentucky and an industrial consortium contributed. It will be operated by a synthetic fuels firm, at least until 1982. Figure 3-1 is an overall view of the H-Coal pilot plant.

Three weeks after the H-Coal startup, the Nation's second major synthetic liquid pilot plant (pictured in Figure 3-2) began operating in Baytown, Texas. Sponsored by DOE and an industrial group headed by the Exxon Company USA, this Exxon Donor Solvent plant is capable of processing 250 tons of coal each day. On September 26, the plant passed its 1,000th hour of test runs—an initial operation that had progressed better than anticipated.

Prior to the H-Coal and Exxon pilot plants, the largest coal-to-liquid plant in the United States had been the Solvent-Refined-Coal plant at Ft. Lewis, Washington. In 1980, this 50-ton-per-day pilot plant passed its sixth year

Figure 3-1—H-Coal liquefaction plant, Catlettsburg, Kentucky

Figure 3-2—Exxon Donor Solvent Plant, Baytown, Texas

of successful operation. Early in the year, a synthetic oil spill at the plant brought Federal and state of Washington officials to the site. By midsummer, the spill site had been cleaned up and inspected by regional environmental officials, and was no longer considered an ecological concern.

With the technical and environmental experience gained from the Ft. Lewis plant and a smaller unit at Wilsonville, Alabama, the Department moved forward during 1980 with designs for two full-scale Solvent-Refined-Coal demonstration plants. These plants, the last in a development chain of progressively larger facilities, will use commercial-scale components. They could start operating in 1984 or early 1985. Each plant is currently projected to cost \$1.4 billion and would process 6,000 tons of high-sulfur coal per day into the energy equivalent of 20,000 barrels of oil. Moreover, they are expected to be the Nation's first synthetic fuel facilities to operate using full-size equipment, and consequently will provide valuable construction and operating information for private firms building commercial plants using a variety of synthetic fuel processes.

On July 30, President Carter and the ambassadors of the Federal Republic of Germany and Japan signed an international agreement to co-fund the proposed Solvent-Refined-Coal demonstration plant to be located near

Morgantown, West Virginia. A week after the White House signing of this agreement, Federal officials met with representatives of two industrial firms in Owensboro, Kentucky, to sign an agreement funding the second Solvent-Refined-Coal demonstration plant. The plant, proposed for Newman, Kentucky, would use a variation of the technology to manufacture both liquid and solid synthetic fuels.

Before beginning construction of synthetic fuels projects, an Environmental Impact Statement must be completed. In September, the Department reached a precedent-setting agreement with the Environmental Protection Agency on the environmental review procedure for large-scale synthetic fuels demonstration projects. The agencies agreed that an Environmental Impact Statement would initially be prepared during the design of a major plant and would permit construction to overlap the final stages of design. As additional, environmentally significant information becomes available in later stages of the project, appropriate documents will be prepared for public review to supplement the original Environmental Impact Statement.

The Department of Energy also proceeded with plans for an advanced coal gasification demonstration plant at Memphis, Tennessee. On May 21, Federal and city officials signed an agreement co-funding the project, currently estimated to cost \$847 million. Construction is

pected to begin in 1981 with completion anticipated for 1984. The plant will use a process developed under Federal sponsorship by the Chicago-based Institute of Gas Technology and will produce a medium-quality synthetic gas suitable for use by nearby industries.

In October 1980, the Department also agreed to fund over the next 2 years the design of a full-scale plant to convert coal into gasoline. The estimated \$3 billion plant is proposed for Baskett, Kentucky.

Two firms working for the Department of Energy to convert high-sulfur coal into high-Btu, or pipeline-quality, gas received approval in 1980 to complete their designs of demonstration plants. In June, the Department told the concerns that it would wait until business proposals, financial agreements, and regulatory approvals had been completed before deciding which of the two projects should be built. Each contractor is expected to provide such information following the completion of its design in mid-1981. One plant is proposed for Noble County, Ohio, and the other for Perry County, Illinois.

In September, DOE added a new industrial partner to its advanced coal gasification demonstration program to design a plant capable of producing a gas that could be burned in an electric powerplant. The company proposed siting the plant adjacent to the Gulf State Utilities' power station in West Lake, Louisiana. The decision to move the process into the demonstration program followed 2 years of testing at the firm's 120-ton-per-day pilot plant at Windsor, Connecticut. In February, the Windsor plant passed its 2,000th hour of operation—a significant milestone.

Scientists also moved closer in late 1979 and early 1980 to extracting significant quantities of synthetic gas from unminable coal seams in the West. In experiments conducted for DOE, portions of a steeply dipping coal seam near Rawlins, Wyoming, were converted to synthetic gas underground. The test in a 23-foot thick coal bed dipping at 63 degrees was the first of its kind in the United States. Coal was gasified during the 40-day test at rates of up to 75 tons per day.

Direct Combustion

In 1980, utilities consumed about 3.5 quads (10^{15} Btu's) each of oil and natural gas in their steam boilers to generate electricity. About one-third of the utilities burning oil today have coal-capable boilers, which means that either they once burned or can now use coal. Many of the remaining oil-designed utilities can be modified to use coal-oil mixtures or to take advantage of such technological advancements as coal gasification. If large numbers of utilities begin displacing oil with coal, the demand for coal could go as high as 100 million tons a year.

Since utilities constitute such a significant oil-

consuming sector, the Department is focusing a large portion of its oil-reducing efforts on encouraging the voluntary substitution of alternative fuels and promoting new economic technologies for electrical generation. Seven of the largest oil-consuming utilities were studied (with their cooperation) during 1980 to identify the barriers to fuel conversion. Because these barriers are plant- and site-specific, they must be studied on a case-by-case basis. Plans for 1981 are to direct efforts toward reducing the barriers to conversion identified by these studies.

The Department's direct combustion program is directed toward promoting the near-term use of advanced technologies to generate electricity or steam. It addresses the problem of backing out oil and gas from existing plants where full conversion is not feasible and, at the same time, addresses the Nation's long-term need for a secure and efficient energy supply. Realizing that a major hindrance to the use of new technologies is the natural aversion to economic risk, several efforts are directed toward encouraging utilities to build and operate advanced-process plants.

The first year's operation of a project using a new method for burning high-sulfur coal cleanly without expensive fuel gas "scrubbers" was completed during 1980 at Georgetown University in Washington, D.C. The technique traps sulfur from burning coal in the boiler using crushed limestone, which prevents the pollutant from escaping through the smokestack. Other versions of this advanced boiler concept, which use a technology called "atmospheric fluidized-bed combustion," have been offered by several commercial vendors.

The Nation's first utility version of the fluidized-bed concept, located at Rivesville, West Virginia, also passed a milestone in 1980 with a 200-hour continuous test run in March. The test program for this boiler is not complete, and the project will be phased out in 1981.

Construction was also begun during the year at Shamokin, Pennsylvania, on a small fluidized-bed boiler capable of burning the wastes left from past anthracite mining operations. Such wastes, called "culm," have accumulated in piles over the past century in parts of northeastern Pennsylvania, and are estimated to contain the energy equivalent of almost 1 billion barrels of oil. This residue is currently unusable in conventional boilers, but the efficient fluidized-bed concept may provide a method for extracting the energy from the culm banks. A similar, although larger, fluidized-bed boiler designed for anthracite is also expected to be constructed at Wilkes-Barre, Pennsylvania.

In June 1980, DOE began a test at Wood-Ridge, New Jersey, of an advanced version of the fluidized-bed boiler. Instead of burning coal at atmospheric pressure, the test unit will operate at roughly seven times atmospheric pressure. This pressurized fluidized-bed concept is par-

ticularly attractive when used in conjunction with gas and steam turbines to generate electricity in a process called "combined-cycle." The beginning of the project followed a 1,000-hour run of a small gas turbine at the fluidized-bed test unit plus successful results from Leatherhead, England, where 1,000 hours of simulated turbine blade tests were accumulated.

A second pressurized fluidized-bed/combined-cycle test facility was completed in 1980 and began operating with coal. This internationally funded facility is located at Grimethorpe, England, and is sponsored by the United States, the Federal Republic of Germany, and the United Kingdom.

A similar combined-cycle system would substitute a coal gasifier for the pressurized fluidized-bed combustor. In October 1980, the Department asked for private sector participation in site-specific feasibility studies for gasification combined-cycle technical demonstration plants.

These early versions of the combined-cycle system will not be as efficient as similar techniques that will emerge from the development program in the 1990's. As a result, the costs of power from the first system would be comparable rather than significantly less than conventional technology; however, the superior environmental performance of the new technology appears to ensure its acceptance in environmentally sensitive regions during this decade.

Another possible near-term alternative is the use of coal-oil mixtures for displacing oil and natural gas in utility and industrial boilers. A mixture of coal and oil containing up to 50 percent by weight (40 percent by heating values) of pulverized coal can be burned in many existing boilers with minimum modifications. The Department of Energy has been working with the New England Power Service Company in Salem, Massachusetts, to demonstrate that coal-oil mixtures can be burned in utilities originally designed for coal but currently burning oil. This program and other supporting research has been quite successful, and a number of coal-oil mixture project planners have applied for assistance under the Alternative Fuels Program and the Synthetic Fuels Corporation.

Advanced Environmental Control Technology

Since most of the coal consumed in the United States will continue to be burned directly, it is necessary to ensure that coal-using facilities will be able to operate while meeting applicable environmental standards. Utilities currently can purchase equipment that will allow them to use coal in environmentally acceptable ways, but the choices are limited. The primary commercial cleaning system available is the scrubber, which uses an aqueous mixture of lime/limestone to clean sulfur from combustion gases in smokestacks. The Department has undertaken near-term

research to address problems associated with sludge. The Department is also studying utility concerns about scrubber reliability, efficiency losses, and equipment space requirements.

In cooperation with the Environmental Protection Agency, the Department investigated the use of additives to lower the costs and to improve the performance of lime/limestone scrubbers. In September, the two agencies began a large-scale test in which adipic acid, a byproduct of the synthetic fiber industry, was added to a scrubber at a Springfield, Illinois, powerplant. In a previous 1-year test at a smaller, experimental powerplant, the additive showed a capability of boosting sulfur removal from 75 to more than 90 percent. Magnesium oxide and formic acid are also being tested as potential additives.

Forced oxidation is another technique that has been investigated by the Department of Energy. This technique could be useful to powerplants using conventional scrubbers, because it converts wet sludge into a dry material that can be used as building materials or soil conditioners.

Another means of disposing of coal combustion wastes was demonstrated in 1980 in a cooperative program between DOE, the state of New York, the Environmental Protection Agency, and the Electric Power Research Institute. Some 18,000 blocks of specially treated coal wastes, weighing 500 tons, were dropped from a barge in the Atlantic waters south of Long Island. Within weeks, marine organisms began accumulating on the artificial reef of submerged blocks, thus creating an attractive feeding ground for fish and aiding the New England fishing industry. Since every 10,000 megawatts of new generating capacity requires more than 160 acres of land each year for disposal, an ecologically beneficial seabed disposal technique may minimize the space problems facing coal-fired powerplants in the future.

The Department also is investigating alternatives to conventional scrubbers, including dry or regenerable desulfurization systems. An important feature of these new systems is that they do not produce the difficult-to-handle wet sludge.

The Department also expanded its program to develop ways of cleaning hot coal combustion gases before they are used in a gas turbine. In April, four firms were selected to develop "hot gas clean-up" techniques that could have relatively near-term commercial potential. A key feature of the systems to be developed is the ability to remove contaminants while the gas is still hot, permitting more of the energy to be transferred to the power-generating equipment.

Heat Engines and Heat Recovery

As much as two-thirds of the energy consumed by utilities and industries is not used but instead is exhaust-

to the environment as waste heat. During 1980, the Department initiated a program to recover low-temperature below 200° F) heat lost from the Department's three uranium enrichment plants located at Portsmouth, Ohio; Paducah, Kentucky; and Oak Ridge, Tennessee.

Heat recovery techniques are under development for systems that operate well above 200° F. Logical candidates for them are small municipal utilities. With this in mind, a waste heat recovery demonstration project got under way in May in Homestead, Florida. This project demonstrated the third DOE-sponsored unit designed to recycle a portion of the waste heat back into additional electricity. The 3.5 million kilowatt-hours generated annually by each system could save at least \$210,000 per year in fuel bills.

Linked to a coal gasifier, high-temperature turbines capable of operating at up to 2,600° F (the usual firing temperature is about 2,000° F) offer the potential for reducing electricity generating costs with fewer pollutants than those emitted by conventional coal-fired systems. Beginning in 1976, two firms began working with the Federal Government to develop two versions of high-temperature turbine technology. One version uses a water-cooled system, the other uses air. In 1980, both firms finished the second phase of the program and completed 3,000 hours of testing. During 1981, the companies will begin engine tests to verify the technology's readiness.

Fuel Cells

Fuel cells, which convert fuel energy to electricity by electrochemical rather than by thermal means, are essentially nonpolluting, noiseless, and potentially quite efficient. Because of their modular construction, they have the added advantage of versatility and can be installed in either large or small units. The environmental characteristics and operating flexibility of the concept indicate that fuel cells could rapidly become a significant source of coal-derived energy.

During the year, the world's first electric utility fuel cell powerplant neared completion in New York City. Thirteen of the fourteen modules that make up the 4.8-megawatt prototype powerplant were delivered and connected, and it is anticipated that the plant will begin operating in April 1981.

Technological improvements made since the beginning of this project have made cogeneration applications possible for phosphoric acid fuel cells fueled by synthetic gas from coal. For more than 3,000 hours, the Department tested under contract a fuel cell cogeneration powerplant. Located in South Windsor, Connecticut, the 40-kilowatt phosphoric acid plant demonstrated an electrical conversion efficiency of 40 percent. When cogenerated heat was included, fuel utilization efficiency rose from 80 to 85 percent. Fuel usage in both residential and commercial sectors

could be reduced significantly by such a system.

Also during the year, the electric and gas utilities each organized a group to promote the commercialization of fuel cells. By sharing information, utilities can learn to use fuel cells in processes that can make effective use of waste heat (such as cogeneration and integrated utility systems) to provide electricity for onsite residential and commercial use. With continuing technological advancements, fuel cells could become a major source of coal-derived energy by the next century.

Magnetohydrodynamics

The magnetohydrodynamic (MHD) process is a highly advanced method for converting heat produced by coal combustion directly into electricity without the use of a steam or gas turbine. This type of power generation is achieved by accelerating an electrically conductive fluid (coal combustion gases heated to over 2,000° C, with the addition of an electrically conductive substance) through a high-intensity magnetic field in the MHD generator, thus setting up an electric field within the fluid and generating electricity. After leaving the generator, the hot fluid or plasma can be used further to generate electricity in a conventional steam turbine unit. This will result in a production efficiency rate of up to one and one-half times that of today's powerplants. In addition to this efficiency potential, MHD systems are inherently capable of cleaning sulfur from coal during the power-producing process, thus eliminating the need for costly flue gas clean-up equipment.

With DOE support, magnetohydrodynamics has progressed to the large-scale engineering development stage. In October 1980, engineers working under a DOE contract at the University of Tennessee Space Institute successfully completed the first test of a coal-fired MHD system. Results indicate that tests at the \$12 million facility can progress to studies involving other major components which, when linked together, will make up the first integrated coal-fired MHD system tested in the United States. Up to that time, MHD tests on the scale of the Tennessee facility had either simulated coal combustion or had involved only individual components, not an integrated system. Various configurations of coal combustors will be tested at the facility over the next 3 years. A larger DOE testing facility was recently completed near Butte, Montana, that will operate at 50 megawatts.

Oil and Natural Gas

Petroleum

Petroleum will continue to be one of the Nation's major energy sources for many years, although vigorous con-

servation measures, driven in large part by rising world oil prices, reduced domestic demand from a 1979 level of about 18.5 million barrels to about 16.9 million barrels per day in 1980. Net oil imports averaged less than 6.3 million barrels a day, a drop of over 20 percent from 1979.

The President's decision to decontrol domestic crude oil resulted in a dramatic increase in drilling activity within the United States. More than 3,000 drilling rigs were active during 1980, a greater number than at any time in the 32 years that records have been kept. Some 59,000 domestic wells were drilled, also a record, and a number that exceeded any expectations of a year ago. Figure 3-3 depicts the number of exploratory hole completions between 1973 and 1980.

Yet, even as activity increases to find and produce new supplies of petroleum, the long-term outlook for major new discoveries has diminished. Consequently, the Department's research and development program is focusing on developing more efficient techniques for recovering petroleum by unconventional methods and for extracting potentially vast amounts of energy products from such unconventional sources as oil shale and tar sands.

Drilling and Offshore Technology

Development of efficient drilling and offshore

technology can have a pronounced effect on the pace at which both conventional and unconventional fossil fuels are produced. The development of offshore energy resources has been constrained by such problems as environmental concerns, long lead-time requirements, lack of long-term investment capital, and a general wariness on the part of industry to invest in potentially risky projects.

DOE is continuing to improve conventional drilling systems and to develop advanced concepts in conjunction with private industry. Activities during 1980 involved high-performance bit technology; an evaluation of various drilling fluids that could be used in wells drilled at depths greater than 20,000 feet and slanted at angles of up to 90 degrees; and the development of new, high-temperature, high-pressure, corrosion-resistant alloys for use in drilling equipment. Working with Sandia Laboratories, the Department also continued its research on water jet drilling as well as inertial guidance systems for controlling precise drilling directions.

In October, DOE successfully installed three systems in the Santa Barbara Channel to measure seafloor earthquakes. Located on the seafloor at depths of 165, 200, and 500 feet, the systems will monitor seafloor responses to earthquakes for 1 year. These systems should be particularly useful for engineering the construction of offshore drilling structures.

Figure 3-3—Exploratory hole completions by quarter (oil and gas)

Enhanced Oil Recovery

Enhanced oil recovery is one of the most promising near-term means for increasing domestic energy production. In the operation of a typical well, only a portion of the existing oil is extracted, leaving about two-thirds in the reservoir. The application of current and advanced recovery techniques could result in the recovery of an additional 18 billion to 52 billion barrels, tripling present domestic reserves. Most of this would be light oil, worth a premium as feedstock for transportation fuels.

However, economic and technological uncertainties have discouraged producers from using advanced enhanced recovery methods. Accordingly, the Department, in conjunction with private industry, continued focusing on the research and development of new recovery techniques during 1980. At the same time, it placed considerable emphasis on analyzing data from ongoing field tests directly funded by DOE and those sponsored through the Economic Regulatory Administration's regulatory program.

One of the enhanced oil recovery processes receiving particular emphasis is micellar-polymer flooding. This technique involves injecting a surfactant, a detergent-like substance dissolved in water, to displace the oil unrecoverable by conventional techniques. Injection of the

surfactant is followed by a polymer solution, and then by the injection of water to force the oil toward a producing well. This injection method is illustrated in Figure 3-4.

In February 1980, a sophisticated micellar-polymer test began yielding favorable results at the giant Wilmington oil field in Long Beach, California. Following injection of the micellar-polymer chemicals during the late summer and fall of 1979, oil production from the pilot project more than doubled in 1 month, from 50 barrels per day in January to 109 barrels per day in February. Production continued to climb to 121 barrels per day in March and then to 171 barrels per day in May.

Also during the year, the Department began a study with the University of Oklahoma to determine whether certain microorganisms injected into the reservoir could produce similar micellar-polymer chemicals biologically. Success of the project will be achieved if life forms can be found that can produce the chemicals for oil recovery at significant rates within an oil reservoir.

In April, the Department began testing a prototype steam-generating system to tap deep, highly viscous oil deposits. The downhole steam generator, which can be lowered into a reservoir as much as a mile underground, is part of the Department's Project Deepsteam. After 5 months of initial testing in a relatively shallow heavy oil field near Bakersfield, California, researchers from DOE's

Figure 3-4—Chemical flooding (micellar-polymer). The method shown requires a preflush to condition the reservoir, the injection of a micellar fluid for releasing oil, followed by a polymer solution for mobility control to minimize channeling, and driving fluid (water) to move the chemicals and resulting oil bank to production wells.

Sandia Laboratories reported that the generator could increase oil production while holding down the release of pollutants into the atmosphere. Instead of escaping into the air, emissions from the unit are either trapped underground or dissolved in water pumped to the surface for recycling. The unit also shows the potential for burning only two-thirds as much fuel as a surface generator, which consumes about a barrel of oil for every three recovered.

The use of steam to free even heavier oil trapped in tar sand deposits was also demonstrated during the year. In October, DOE researchers completed their first attempt to recover oil from tar sands by injecting hot, pressurized steam into a 490-foot deep, quarter-acre test zone near Vernal, Utah. Five months of testing showed that the steam could be made to move through the tightly packed sands and raise the reservoir's temperature to a maximum of 465° F, high enough to thin the heavy oil sufficiently for production. About 1,000 barrels of oil were produced during the test.

Oil Shale

For several decades the vast U.S. oil shale resources have attracted development interest. Despite this, the high costs of present extraction technologies, the limited quantity of oil shale available to private industry, and the expense of upgrading and transporting shale oil to existing markets have precluded commercial development.

The Department of Energy's Oil Shale program seeks to mitigate barriers and to ensure that three basic conditions for commercial oil shale production exist. The first condition is that the resource be accessible to private industry for development; the second is that effective extraction technologies are developed; and the third is that markets exist for the products of oil shale operations. The program's goal is a production rate of 400,000 barrels of shale oil per day by 1990.

Although commercial size (50,000 barrels per day) shale oil facilities do not yet exist in the United States, many activities are going on ranging from preliminary design to the construction of commercial-scale facilities. Working either independently or in joint venture, several companies are contemplating moving into commercial operations on the premise that Federal Government actions to eliminate restraints to commercialization will be successful.

Two of the three firms that submitted proposals to DOE in 1979 to design a co-funded surface oil shale commercial-sized plant were awarded contracts in June 1980. Under these contracts, the companies will design facilities that, if built, will form the first module of a full-size oil shale plant.

The Department of Energy continued its work on smaller-scale tests of more advanced techniques that rely

on the underground, or *in situ*, heating of oil shale (illustrated in Figure 3-5.) Production of shale oil was begun as a DOE-sponsored project in Colorado (using underground steam injection) and in Utah (using a method for retorting a thin, shallow shale seam horizontally). A third *in situ* project using a vertical retorting technique (which produced almost 47,000 barrels of oil in a 1979 test) began preparations for a larger, twin-retort test. Each retort will be roughly 160 feet square and 300 feet deep. Late in 1980, engineers successfully exploded a series of charges in an underground shale seam to break the rock into small pieces in preparation for heating the shale.

The Department also began two new projects during the year to develop novel oil shale processing techniques. One, with the Illinois Institute of Technology's Research Institute, will use radio-frequency waves to heat and extract shale oil. The other, with the Institute of Gas Technology, will process lower-grade eastern shales in a hydrogen atmosphere to boost the yield of gaseous and liquid hydrocarbons.

Legislation passed in 1980 resulted in a \$3-per-barrel shale oil production tax credit and improvements in the investment tax credit that became part of the Windfall Profit Tax Act. In addition, grants totaling \$2.7 million were awarded for feasibility studies and for assessing the socioeconomic impacts of oil shale development.

Besides these financial incentives, the Department of Energy and the Department of the Interior began to study the land leasing issues that have deterred oil shale development. As a result, the Department of the Interior and the Administration sponsored legislative initiatives to reduce some of the constraints on oil shale leasing. DOE also sponsored cooperative programs with the Environmental Protection Agency to reduce uncertainties about air quality regulations and worked with the Department of Housing and Urban Development to develop a prototype program to address community and housing problems attending the commercial development of oil shale in Colorado and Utah.

Another activity accomplished during the year was the publication of two oil shale reference books. One, the *Candidate Shale Oil Project Book*, is a handbook describing the status of oil shale projects that are at or near the commercial development stage. The other directory was produced with the cooperation of the Environmental Protection Agency. This document is entitled the *Government and University Oil Shale Directory*, and lists all people in government and universities involved in scientific, engineering, and management activities related to oil shale.

Economic analyses and evaluations concerning shale oil production are to be continued during 1981 with the objective of expanding the industry and determining the need for continuing or modifying Federal incentives. In addition, state-Federal production management planning will

Figure 3-5—In situ combustion. Heat is used to thin the oil and permit it to flow more easily toward production wells. In a fireflood, the information is ignited, and by continued injection of air, a fire front is advanced through the reservoir. Mobility of oil is increased by reduced viscosity caused by heat and solution of combustion gases.

consider such aspects as site selection, water availability, and socioeconomic impacts. Under the oil shale program, socioeconomic assistance of the type given to states will also be extended to local governments. Marketing activities will be directed toward incentives for converting refineries to process shale oil. Such incentives should encourage shale oil to enter the transportation fuels market, where it could make a significant contribution.

Natural Gas

Over the last few years, the natural gas market has undergone an encouraging transition. Since the Natural Gas Policy Act of 1978 was signed into law, the decline of domestic natural gas production has been checked, and production has leveled off at about 20 trillion cubic feet per year. From a low of 7.6 trillion cubic feet in 1976, annual reserve additions increased to 14.3 trillion cubic feet in 1979. Further improvements in natural gas policies could substantially reduce the Nation's oil vulnerability.

The single largest addition from domestic sources to interstate pipeline supplies in the next decade is expected to be natural gas from Alaska's North Slope. The recent cooperative agreement for importing gas from Mexico also should significantly augment our supplies. Canada, which has long been a significant supplier of gas to the northern

and western regions of the United States, should continue to be a stable source of gas supplies for the United States.

Unconventional Gas

The amounts of natural gas dispersed in such unconventional geologic formations as the Devonian shales in the East, tight gas sandstone formations in the West, coal seams, and the geopressured aquifers along the Gulf Coast are potentially quite substantial. Up to this time, the expense of recovering this gas has not proved economical; however, rising world oil prices are making its exploitation increasingly attractive. In addition, three categories of unconventional gas [geopressurized coal bed methane, Devonian, and deep gas (7,000 to 15,000 feet)] were decontrolled by the Natural Gas Policy Act of 1978. Gas from tight sands now receives a special incentive price equal to 200 percent of the section 102 (new) gas price in the National Gas Policy Act.

During 1980, DOE conducted field tests with six companies to demonstrate techniques for recovering gas from Devonian shales. The tests revealed that advanced stimulation technology—fracturing the reservoir with chemical explosives or by injecting massive amounts of high-pressure water—will produce considerably more natural gas than the more conventional chemical wellbore-fracturing methods.

Twenty geologic basins were identified as containing significant amounts of gas in tight sand formations. Particular attention was given to four of the basins where the technological problems of recovering gas from tight sands are more severe than in others. Two important field experiments were conducted during the year. One involved the injection of dry gas into the Wattenberg Field in Colorado to fracture the reservoir rock, and the other involved a multiwell test experiment in the Piceance Basin of Colorado.

In an effort to develop a way to capture and use the almost 100 billion cubic feet of methane gas that escapes or is vented from U.S. coal mines annually, a Department-sponsored project began in September to channel gas out of a Pennsylvania coal mine into a nearby electrical generating plant. The project was conducted at a mine near Washington, Pennsylvania; it was the first successful project to use methane gas from a coal mine to generate power at the mine site.

Geopressed aquifers are another unconventional gas resource being developed by the Department of Energy. Considered part of the Department's Geothermal Program, this development program is described on page 5-22 of this report.

Leasing Programs

The DOE Organization Act transferred certain responsibilities for leasing and developing federally owned energy resources from the Department of the Interior to the Department of Energy. Recognizing the need for cooperative efforts, the two Departments signed a Memorandum of Understanding in September 1978, directing DOE to establish energy production goals for all energy leasing resources and the Department of the Interior to provide DOE with the necessary energy resource information to set the goals. DOE updates and revises production goals every 2 years and designs new regulations to develop and implement alternative bidding systems, establish diligence requirements for operations on Federal leases, foster competition for all Federal leases, acquire and dispose of Federal royalty oil interests to be taken in kind, and set production rates.

During 1980, DOE's Leasing Policy Development Office prepared Outer Continental Shelf (OCS) alternative bidding systems, and royalty oil and net profit share regulations. OCS royalty oil, OCS oil and gas bonus bidding with fixed royalty, OCS royalty bidding with fixed cash bonus, and OCS bidding with sliding scale royalty were published in the *Federal Register* in February 1980. On May 15, 1980, fixed net profit share bidding systems for OCS oil and gas and accounting procedures for determining net profit share payments were published for final

rulemaking. On May 28, 1980, the OCS oil and gas joint bidding requirements were published in the *Federal Register*. These new bidding systems are expected to encourage competition for OCS leases and to provide the Federal Government with several new alternatives for encouraging private industry to explore offshore oil and gas resources.

The Department of Energy also initiated an analysis of the OCS oil and gas permitting systems used by Federal, state, and local governments. This analysis is continuing into 1981 with results and recommendations to be submitted for DOE Secretarial approval by the end of the same year. This analysis should help accelerate leasing by eliminating duplicative Federal/state permitting requirements. Moreover, DOE will be able to determine what kind of OCS oil and gas development regulations are needed to accelerate exploration, development, and production.

Other major leasing programs under way during 1980 include the following:

OCS Oil and Gas: Initiation of analysis and formulation of OCS Supplemental Leasing Systems were undertaken during the year to accelerate leasing and drilling on the OCS, particularly in frontier areas. In July 1980, a Notice of Inquiry was published in the *Federal Register* to request public comments on OCS oil and gas work commitment bidding. Figure 3-3 depicts the number of exploratory wells completed by year.

Ongoing activities include involvement with OCS oil and gas lease and Department of the Interior/Environmental Impact Statement, review and lease sale approval, as well as review of OCS oil and gas production rates policy.

Onshore Oil and Gas: The major accomplishment in this area was the advertisement of the onshore oil and gas, coal, and geothermal permitting analysis procurement in July 1980.

Oil Shale, Tar Sands, and Geothermal: The focus was on participation in an oil shale, tar sands, and geothermal task force.

Land Withdrawals

DOE plans to continue this program through 1983 to provide the Secretary of Energy with information required to reach decisions on the use of U.S. public lands for wilderness or vehicle uses versus use for mineral exploration.

In addition to its major leasing policy programs, DOE has conducted analyses and evaluations of competition and diligent development in OCS leasing. This project was useful to DOE in deciding to defer promulgating OCS diligence requirements at least through 1981.

During 1980, the Department prepared the OCS Leasing Initiatives. DOE also began developing a coal leasing initiatives document. New leasing initiatives must still be developed for coal, oil shale, onshore oil and gas, and tar sands.

Future plans include an analysis of present oil and gas leasing policy to determine its effect on developing 375 million acres considered prospectively valuable for oil and gas resources. This includes working with the Department of the Interior to include frontier acreage in the future and to accelerate leasing and drilling on the Outer Continental Shelf. DOE also plans to assess the rates of production of oil and gas on the 100 million acres now under lease and to

evaluate permits required for oil and gas leasing and development to streamline the leasing and permitting process.

Future plans involving the Outer Continental Shelf include reviewing OCS oil and gas lease terms and conditions leading to approval of lease tract sales, analyzing OCS diligence requirements to determine if more stringent regulations are needed, assessing competition in bidding on OCS tracts, and developing and promulgating regulations for OCS oil and gas bidding systems and coal diligence. Finally, the Leasing Policy Development Office plans to develop geothermal production goals as well as interim oil shale, coal, and synthetic fuels production goals.

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Chapter 4

Nuclear Energy

Introduction

In many respects nuclear power is an attractive choice for supplying energy as the Nation makes the crucial transition from an oil-dependent economy to one securely based on abundant domestic sources. Nuclear technology has proven its value in over two decades of commercial service, and it is now providing over 10 percent of the Nation's electrical production—and as much as 50 percent of the electrical production in areas of the Midwest and New England. Not only does nuclear energy compare quite favorably to other energy options in economic respects, but it also has many environmental advantages. And, despite the accident at Three Mile Island, it has a record of safety unmatched in the energy industry. Nuclear electrical generation has provided needed stability during periods when other sources of energy were in short supply, such as the Arab oil embargo of 1973-1974, the natural gas shortage of 1976-1977, and the nationwide coal strike during the winter and spring of 1978.

Despite these advantages, nuclear energy has not made the contribution once expected of it. This was true before the accident at Three Mile Island in Pennsylvania, and it results from problems that are common to the electric utility industry as well as from concerns about safety, waste management, and the proliferation of nuclear materials.

Nuclear energy is almost uniquely associated with the generation of electricity. It is therefore helpful to view it in the context of the electric utility industry, whose problems began in the early 1970's.

Rising oil prices at that time triggered increases in all energy costs, and the traditional 7-percent annual growth in electricity consumption dropped to less than half that rate. This sudden reduction in growth left utilities unable to predict demand even on a yearly basis, much less over the 7- to 10-year period required to build a nuclear powerplant. Thus began a period of retrenchment for electric utility companies. As utilities reexamined their plans to build new facilities, nuclear plants were at a particular disadvantage because of the long lead time required for construction, and the passthrough of extra "fuel adjustment" costs for oil allowed by state regulatory commissions. Public concern about the safety of nuclear plants prolonged the already lengthy—and costly—licensing process, contributing further to the rising cost of bringing new plants on line. Finally, the accident at Three Mile Island intensified this concern about safety.

Given these concerns, the Department of Energy initiated a number of programs to develop technologies and improve safety practices to enhance the nuclear option. Primary emphasis is placed on reinforcing the present generation of fission systems—the light water reactor using a once-through fuel cycle—while maintaining a strong research base for fission breeder technology. The findings of the independent commission President Carter appointed in 1979 to investigate the Three Mile Island accident, which covered such areas as regulatory procedures, training of operating personnel, emergency planning and response, and sustained operational overview, provided both the Government and the nuclear industry with a basis for a substantial reinforcement of safety procedures.

DOE is undertaking programs to extend limited

domestic uranium resources through development of more efficient fuels. Other efforts are aimed at giving a more accurate assessment of the extent of both domestic and foreign uranium resources, thereby providing information important to decisions by government and utilities on when new and potentially inexhaustible technologies, like the fission breeder, may need to be deployed.

The past year has witnessed notable progress in resolving major concerns affecting the expansion of nuclear power. Two comprehensive studies on the proliferation issue have been completed (see Chapter 15). The Non-proliferation Alternative Systems Assessment Program (NASAP) study, begun by DOE in late 1976, analyzed nuclear fuel cycle alternatives and developed technical data to support U.S. international policy objectives and to assist policymakers in framing future U.S. nuclear activity. The International Nuclear Fuel Cycle Evaluation (INFCE) provided a forum for the 71 participating nations and international agencies to consider alternative technical and institutional methods that could increase the barriers to nuclear weapons proliferation associated with the civilian nuclear fuel cycle.

In coming to grips with the issue of nuclear waste storage and disposal, 1980 was a watershed year. In February, President Carter announced the Nation's first comprehensive program for nuclear waste management. A State Planning Council was established to facilitate state and local government participation in waste management decisions. The Department is expanding its aggressive and wide-ranging programs directed toward the safe solution of the waste management issue in a way that is acceptable to the public. Work was started on a National Plan intended to describe in detail the programs of the Federal agencies having nuclear waste management responsibilities. Public participation is an integral element of the process for developing the plan.

One specialized area of Department activity outside commercial nuclear power is the development of nuclear equipment for space missions undertaken by other Federal agencies. This program also investigates and demonstrates the many beneficial uses of radioisotopes in terrestrial applications.

The technology developed by the Naval Reactors program during the early 1950's formed the basis for the civilian application of light water reactors and continues to contribute to the nuclear fission development effort. Because of the close tie-in between its technology and that developed for other nuclear energy programs, the Naval Reactors development program is placed organizationally under the cognizance of the Assistant Secretary for Nuclear Energy. For budget purposes, the Naval Reactors program is funded within the Department's Atomic Defense activities mission area; it is discussed in Chapter 13.

Conventional Reactor Systems

Light Water Reactors

Current policy directing nuclear development emphasizes the key role of the light water reactor. Programs supported by the Department of Energy in this area seek to improve plant safety, to reduce occupational exposure to radiation, to increase plant productivity, and to improve the efficiency of use of uranium fuel.

Work during 1980 was directed toward ongoing programs to further develop and demonstrate higher burnup fuels—which can be used more efficiently in light water reactors. These new fuels could reduce fuel consumption by as much as 15 percent by 1988, and by 30 percent or more by the year 2000.

Radiation dose reduction and productivity improvement activity during 1980 focused on reducing radiation source levels, the incidence of failed components in radiation fields, and manual surveillance, inspection, and maintenance requirements. When achieved, these reductions will improve productivity by reducing the downtime of nuclear plants. To encourage widespread commercial application of these improved technologies, the electric utility industry and its equipment and service suppliers are directly involved in these programs and share the costs. Significant benefits before 1985 are expected to include conserved uranium, less dependence on imported oil, and reduced radiation exposure levels for operating personnel.

DOE is seeking to improve reactor safety by developing technology to reduce the probability and consequences of reactor accidents. Emphasis is placed on the prevention of accidents through use of a defense in-depth discipline, which stresses reliability of operating equipment and backup safety systems that would impede the progression of accidents. Increased attention is also being given to the human element in reactor operation and support activities. Utilities and supplier industries are involved in these activities, which are coordinated with the Nuclear Regulatory Commission and the Electric Power Research Institute.

Safety activities during the year came largely in response to the findings of the Kemeny Commission, the panel President Carter appointed to investigate the accident at Three Mile Island. Those findings and the Department's activities both address the need for more reliable systems and safety components, for improvements in the relationship between nuclear operators and the nuclear power system, and for the creation of a national repository of information on safety in plant operations. These activities will continue in 1981 and 1982.

In response to the President's directive, the Department signed a participation agreement in September 1980 with the Institute of Nuclear Power Operations, an independent organization dedicated to establishing "bench

marks of excellence" in the operation of nuclear powerplants. DOE is conducting cooperative activities with the Institute to assure high-quality training of personnel and continued, safe, reliable operation and maintenance of civilian nuclear powerplants.

Three Mile Island Activities

The Department initiated a broad program to improve the understanding of the March 28, 1979, accident at the Three Mile Island nuclear electric plant in Pennsylvania and the response of nuclear powerplant components, systems, and materials to all accidents. This program is also aimed at disseminating the information obtained to improve the reliability and safety of nuclear powerplants and to restore them safely to operation in case of accident.

To meet these objectives, the Department established a technical integration office at the Three Mile Island site. There, experts study not only the accident itself but also the response of nuclear plant systems to accidents in general. A data bank will be opened to collect and file, in an archive, instruments and electrical equipment relating to the accident. This will be done after they have been removed from the containment building, tested, and analyzed. Investigators will also determine how the various radioactive isotopes released within the containment building were transported and deposited, and how to improve decontamination techniques. Improvement in the methods for handling and disposing of contaminated materials from cleanup operations (such as rags and shoe coverings) will also be sought.

Another important element of the program will be examination and assessment of core damage and damaged fuel in hot cells. The Department is cooperating with industry in this undertaking. Foreign participation is also being encouraged, both to gain international acceptance of its findings and to minimize its cost.

High Temperature Gas-Cooled Reactor

While the fission energy program has historically focused solely on the generation of electric power, the high-temperature gas-cooled reactor concept offers potential applications for production of high-quality steam for the cogeneration of electricity and process steam and the direct production of high-temperature process heat. A major energy market exists in the industrial use of process heat and process steam, which today is largely supplied by fossil fuels.

The focus of the high-temperature gas-cooled reactor program has, therefore, been shifted away from its earlier emphasis on electrical generation. Today, emphasis is on generation and nuclear process heat production for such

uses as nuclear steam reforming of methane, coal gasification, coal liquefaction, oil shale retorting, and hydrogen production, as well as the many and varied industrial applications for high-temperature process steam using steam-electric cogeneration plants.

Significant progress was made in 1980 toward defining the process parameters, plant design characteristics, market potential, and industrial incentives needed for development of all these advanced nuclear process heat technologies. Because of limited budget resources and other priorities in the fission energy program, the Administration recommended termination of this program in 1981. However, Congress decided to continue funding at \$40 million.

Advanced Reactor Systems

Research reactors are used throughout the world for peaceful purposes, from energy development and industrial applications to medical and industrial research. Yet most of these reactors use high-enrichment uranium—a potential weapons material.

Replacing this high-enrichment uranium with reduced-enrichment uranium could considerably lessen the risks of proliferation. Over the next 7 years, the Department estimates that the development of these alternative fuels should significantly reduce the use of high-enrichment uranium in research reactors. Possible exceptions will be a small number of high-powered reactors with more sophisticated experimental missions; but here, too, DOE hopes to develop advanced fuels that, in the long run, could allow the U-235 enrichment requirements to be lowered to 20 percent even in medium- to high-powered reactors.

Technology and production practices have been advanced to ensure that these new fuels are produced in time to meet this schedule. During the year, the Department began fabricating reduced-enrichment uranium test assemblies for a full core reactor physics demonstration at the 2-megawatt Ford Nuclear Reactor. Reduced-enrichment uranium assemblies to be used in higher power research reactors were also built. In 1981, the two design assemblies will be inserted in their respective reactors, where reactor physics, thermal-hydraulic, and fuel-properties data will be gathered to support future licensing of reduced-enrichment uranium applications.

Breeder Reactor Systems

Liquid Metal Fast Breeder Reactor

The breeder reactor is one of the long-term options available to the United States for an essentially inexhaustible source of energy. During 1980, DOE continued its active program for breeder reactor research. The major goal

Figure 4-1—The Fast Flux Test Facility in Richland, Washington

of the program is to provide for strong research and development in required technology areas to support the option of a near-term commitment to a next-generation liquid metal fast breeder reactor developmental plant.

At the Fast Flux Test Facility in Richland, Washington (see Figure 4-1), the Department is testing fuels and materials as well as documenting plant performance and maintenance needs for any future fast breeder reactor. The program's first area of concentration last year was to bring the facility to power. Construction of the facility was essentially completed, criticality in the reactor was achieved, and acceptance-test procedures leading to full power operation were performed. At 1:23 a.m. Tuesday, December 23, 1980, the Fast Flux Test Facility was operated at 100 percent of the full power rating (300 megawatts thermal). This is the highest power level ever achieved in a breeder reactor in the United States. All systems performed as expected.

A second major area of program emphasis was to advance the conceptual design of a developmental plant. The purpose of this effort is to gain information regarding overall plant safety, environmental acceptability, proliferation resistance, economics, and reliability. This will pave the way for more informed decisions on a developmental plant that could serve as the next logical

step in technical advancement of the liquid metal fast breeder reactor. During 1980, key technical features and parameters were established for the plant design. The developmental plant conceptual design will be completed and a report will be forwarded to Congress in 1981.

Finally, the Department's breeder research and development program made progress in the areas of large sodium components, fuels, safety, physics, and qualification of materials and structures. Maintaining a strong technological base will facilitate the deployment of breeder reactors.

In 1977, the President directed deferral of breeder commercialization activities and requested that Congress terminate the Clinch River Breeder Reactor demonstration project while alternative fuel cycles are studied. A number of factors have led to the decision to slow down the pace of breeder development. For one thing, projections of growth in demand for electricity have dropped by about one-half since the 1973-1974 oil embargo. Also, light water reactor deployment has fallen off, suggesting that uranium resources will last longer. At the same time, estimates have increased of the amount of uranium likely to be available at prices that make the light water reactor attractive. Concern over proliferation of nuclear weapons has also contributed to deferred deployment of the breeder.

Fuel Cycle

If breeder reactors are to be deployed in the future, reprocessing techniques must be developed to recover excess fissile materials produced during breeder operations. The Department is therefore developing and demonstrating proliferation-resistant reprocessing technology with reduced occupational exposure, improved environmental protection, and enhanced operational reliability.

Much of the required equipment has been designed and fabricated as individual components. The next step is the integration of the individual components into complete systems. This integration will be accomplished in a new facility, the Integrated Equipment Test facility. In 1980 the detailed design of the facility was completed and construction initiated.

The facility's Remote Operations and Maintenance Demonstration section should be completed in 1982. Integrated operation and remote maintenance of major head-end equipment items will be investigated on a nonradioactive basis using depleted uranium feed. Later, the Integrated Process Development area of the Integrated Equipment Test facility will be activated to test the solvent extraction and associated systems of the reprocessing operations.

The ultimate demonstration of fast breeder fuel reprocessing will take place in a Hot Experimental Facility using fully irradiated fast breeder fuels, initially from the Fast Flux Test Facility. A conceptual design of the Hot Experimental Facility has been completed and a design report issued.

Water-Cooled Breeder

The principal advantage of the water-cooled breeder is that its fuel cycle uses thorium, a fertile and relatively abundant material. The potential energy in domestic thorium reserves is many times greater than that of known fossil fuel reserves and approximately a third of domestic established and probable uranium reserves. Successful development of the water-cooled breeder could make 50 percent of these thorium resources available for power production.

Other advantages of the water-cooled breeder include its use of proven light water reactor technology and its compatibility with conventional pressurized water reactor plant designs. These features make it possible to convert existing and future pressurized water reactors to breeders without major modifications.

A reactor core using this fuel system is now operating in the Shippingport Atomic Power Station in Pennsylvania. It is expected to operate for another 2 to 3 years before being sent to the Expended Core Facility for a

detailed determination of reactor performance, including breeding. At that time, the expended core is expected to contain about 1 percent more fissionable material than it did at the time of initial loading.

The core's performance continues to be evaluated, providing valuable information not only on the core itself, but on all aspects of light water reactors. DOE is assembling technical information on these subjects and others pertaining to the water-cooled breeder and distributing this information throughout the nuclear industry to help scientists and decision-makers evaluate these concepts.

Plans and preparations for the eventual shutdown and end-of-life testing of this thorium-uranium core continued during 1980 at the Shippingport Plant. Particular emphasis was placed on designing and procuring the equipment necessary to remove, disassemble, and examine the expended core. Development of uranium-thorium fuel systems also continued, with emphasis on advanced fuel element and reactor designs, as well as fuel fabrication techniques.

Gas-Cooled Fast Breeder Reactor

The gas-cooled fast reactor was included in the Nation's fission energy program as a backup to the liquid metal fast breeder reactor, should the latter encounter insurmountable technical problems. After more than 25 years of successful experience with sodium-cooled reactors (liquid metal fast breeders), the Department does not foresee any insurmountable problems that would require switching to an entirely different coolant. With no need or market for an alternative coolant, the Administration is phasing out work on the gas-cooled fast reactor. Completion is scheduled for the end of 1981.

Special Nuclear Systems

Space and Terrestrial Systems

Scientific missions in space often last for years, and they require compact and assured sources of power. To meet this need, DOE is developing, for other Federal agencies, nuclear thermal and electric power devices for use in the navigation, communication, and sensing systems of a number of space programs.

To further guide design improvements, DOE continued its analysis of power data from the National Aeronautics and Space Administration's Viking 1 and 2, Pioneer 10 and 11, and Voyager 1 and 2 spacecraft. The onboard nuclear power units continue to supply the electrical energy needs of these missions, as demonstrated by the spectacular pictures of Saturn sent by Voyager 1 in November 1980. Significant progress was made during the

Figure 4-2—Sandia Laboratory's sludge irradiation facility

year to increase the efficiency of radioisotope heat sources in spacecraft systems. Improvements were also made in the design of static thermoelectric devices that convert heat into electricity.

Radioisotope thermoelectric generators are being developed by DOE for NASA's Galileo spacecraft scheduled to be launched in 1984. The generators are expected to produce 120 watts or more at 95-percent reliability up to 5.7 years after fueling. The same type of generator is to be used in the 1985 International Solar Polar mission in which two spacecraft will circumnavigate the Sun, each orbiting in opposite directions around the polar axis. Production of the general purpose heat source fuel pellets for both these missions began last year at the Savannah River Plutonium Fuel Fabrication Facility.

At the Los Alamos Scientific Laboratory, development continued during the year on the space power advanced reactor. Preparations are being made there for

large power systems requiring 10 to 100 kilowatts. Current systems produce a few hundred watts.

The technology developed for spacecraft power needs can find terrestrial uses. The principal example of this space-to-terrestrial technology transfer is the disinfection of sewage sludge. Last year, the cesium-137 pilot sewage sludge irradiator at the Sandia Laboratories demonstrated that sewage sludge can be disinfected by irradiation. The approach involves the application of gamma radiation and decay-heat available from the cesium-137 isotope. The resulting material could be used as fertilizer, soil conditioner, or cattle feed. An immediate result of this program last year was the inclusion of a demonstration irradiator in a plan by the City of Albuquerque, New Mexico, to upgrade its wastewater treatment facilities. Operation is expected in 1984. Figure 4-2 shows a scientist working at the Sandia Laboratories experimental sludge irradiation facility.

Advanced Systems Evaluation

To provide management with comprehensive data on which to base decisions regarding the direction and emphasis of advanced nuclear systems technologies, DOE maintains the capability to assess advanced nuclear concepts and applications. Assessments take into account the economic, environmental, social, and institutional factors of the systems or concepts being examined.

Evaluation activities during 1980 concentrated on nuclear cogeneration systems that simultaneously produce electricity and process heat. Today, requirements for industrial process and district heat account for almost 30 percent of domestic oil consumption and 60 percent of natural gas consumption (or the energy equivalent of 10 million barrels of oil each day). These needs could be largely served through the application of existing reactor technology, thus reducing dependence on fossil fuels. A secondary effort is directed toward the assessment of effective use of nuclear powerplant waste heat for aquaculture and agriculture.

Together with the Department of Housing and Urban Development and other Federal agencies, DOE participated during the year in developing a national district heating strategy. In St. Paul, Minnesota, steps were taken toward implementing a 200-thermal-megawatt district hot water system, using a coal plant as the generation source. The design of the system is already well under way. Studies were begun on the retrofitting of nuclear plants for cogeneration or district heating.

The Department is also assessing improved methods of nuclear powerplant siting and evaluating possible system component modifications. A comprehensive field test was conducted on the effects of heat and moisture releases from a large powerplant complex. The Department also evaluated a site in South Carolina to determine if it could support a 12-unit energy center and at the same time initiated studies of a site in Utah for a 9-unit center.

Construction began last year on a 10-megawatt dry/wet cooling tower demonstration unit in Bakersfield, California. By varying moisture releases according to changing weather and climatic conditions, this computerized system will give plants greater environmental flexibility and improve their chances of gaining siting approval. The system was jointly developed by the Department and the Electric Power Research Institute; the latter has assumed responsibility for the design and construction phases. DOE will contribute funding for operation beginning in 1981.

The systems evaluation program also maintains a data base consisting of capital, fuel, operating, and maintenance costs for conventional and advanced nuclear systems, as well as for systems using fossil energy technologies. This information is designed to keep nuclear

energy competitive with the alternatives and is therefore continually updated.

Advanced Isotope Separation Technology

The Department is developing a technology that will permit more economical enrichment of uranium fuel. Uranium to be used in light water reactors must be enriched; the concentration of the fissionable isotope, uranium-235, must be increased from its normal 0.711-percent level to about 3 percent. However, approximately 0.20 percent U-235 is left in the residue (called depleted tails) of the enrichment process. If this U-235 concentrated in the tails could be economically recovered and enriched, the Nation's usable uranium resource base could be increased by 16 to 19 percent.

Improving the technology used to enrich uranium involves the development of three advanced isotope separation processes—two laser methods and a plasma concept. Demonstration of these processes will establish the principles and components required for the design of an engineering demonstration facility.

The ability of these three processes to meet program goals was demonstrated during the year. Not only was there a significant increase in the amount of enriched uranium collected, but a better understanding of the theory of molecular laser isotope separation was achieved as well. In addition, a uranium vapor source that routinely operates at minimum production densities was demonstrated for the plasma separation process.

Construction of preprototype systems for all three methods proceeded on schedule, with completion scheduled for 1981. Demonstration of a production-sized copper vapor laser and extractor is also planned for 1981. Researchers hope to achieve the minimum separation factor required for the development of a large-scale molecular isotope separation plant.

Commercial Nuclear Waste

Commercial Waste Management

The goal of commercial waste management is to develop methods and facilities for the isolation from the biosphere of the various forms of commercial nuclear waste. The underlying objective is to ensure the long-term protection of the public from commercial nuclear wastes.

The scientific community has spent years evaluating the various available disposal methods for spent nuclear fuel and other high-level wastes. The consensus is that these wastes should be immobilized, sealed in containers, and placed in mined repositories within deep geologic formations. The February 1980 Presidential policy statement on waste management established this approach on an in-

Figure 4-3—Reference repository—artist's conception of a typical commercial nuclear waste management repository

terim basis, pending completion of an environmental impact statement required by the National Environmental Policy Act.

The final Environmental Impact Statement on the Management of Commercially Generated Radioactive Wastes was issued in October 1980. This document was based on testimony given during several public hearings and on the more than 2,000 comments contained in 200 letters that were received on the subject. The statement provides descriptions and evaluations of alternative disposal methods, and it concludes that mined repositories should be the reference technology.

Last year, the Department made considerable progress in evaluating a number of potential repository sites in different geologic environments. This work followed exploratory field studies in salt domes (Louisiana, Mississippi, and Texas), bedded salt (Utah), basalt (Hanford site, Washington), and tuff (Nevada Test Site, Nevada). The Department also is taking steps to expand site exploration to include other geologic media (crystalline rock, for instance) in other regions of the continental United States.

When four to five sites have been evaluated as potentially suitable, one (or more) of these sites will be selected

for a licensed, permanent disposal facility to be operational by perhaps the late 1990's. These repositories will be capable of accepting spent fuel or reprocessed waste from both the commercial and defense sectors. Figure 4-3 is an artist's conception of such a repository.

Technical plans for disposal programs were updated and approved during 1980. The Nuclear Regulatory Commission and the Environmental Protection Agency are developing the criteria needed to establish performance levels for the various components of waste isolation systems. These criteria are scheduled to be issued for public comment by the end of 1981.

A broad technical base is being developed for waste isolation systems, with special emphasis on the development of waste packages designed for specific geologic media. An earth sciences technical plan, jointly developed by the Department and the United States Geological Survey, was issued to help resolve earth science uncertainties.

The Department also made substantial progress in field testing. In one test, spent fuel was encapsulated at Nevada's Engine Maintenance and Disassembly Facility, then placed underground at the Climax Granite Facility.

Heater tests in basalt began last year at the Near Surface Facility in southeastern Washington, and testing was completed last year in salt formations at Avery Island, Louisiana. In these tests, heaters were placed underground to simulate the effects that heat generated by spent fuel would have on canisters, the host rock, and the migration of ground water. Borehole plugging tests in salt commenced, while preparations for similar tests in basalt are near completion.

International cooperation in field testing activities continued last year. One experimental program in granite progressed in Sweden, while cooperative programs were planned with both Canada and the Federal Republic of Germany. A cooperative effort by Federal, state, and tribal governments is essential to the success of nuclear waste management. Last year, President Carter laid the groundwork for this policy through an Executive order establishing a State Planning Council to advise the President and to work with Congress in implementing decisions on waste management and disposal. The council will recommend ways for state and local participation in waste management activities and planning. Through the policy of consultation and concurrence, DOE is establishing a good working relationship with state and local governments and tribal groups in developing and implementing the waste management program.

Remedial Actions Program

The Department maintains a program to oversee the decontamination and decommissioning of all the surplus facilities that it owns. In addition, DOE evaluates the need for and conducts remedial actions to eliminate possible harmful effects resulting from residual contamination at former laboratories or processing sites. Remedial action has also begun at inactive uranium mill tailings storage sites and surrounding properties as mandated by Congress.

Under current radiological criteria, some 30 sites formerly under the Manhattan Engineer District or the Atomic Energy Commission will need remedial work before they can be returned to unrestricted use. When this work is completed, these sites would be suitable for virtually any purpose—commercial, recreational, or other.

During 1980, remedial work began on slightly contaminated sites in Middlesex and Jersey City, New Jersey. In preparation for remedial action, the State of Colorado is performing remedial work to limit radiation exposure stemming from uranium mill tailings used in construction in the Grand Junction area. The Department provides 75 percent of the funding for this project, and the State of Colorado provides the rest. Of the approximately 750 structures (including homes, schools, and commercial buildings) identified for remedial work, about half have

been completed. The rest are scheduled for completion by 1987.

In cooperation with state governments, the Department of Energy also is authorized by the Uranium Mill Tailings Radiation Control Act of 1978 to perform remedial action at 25 inactive uranium mill tailings sites located in nine western states and Pennsylvania (this latter state having signed a cooperative agreement with DOE for this purpose). During 1980, plans were made for the management of the program, including the business of acquiring the major program contractors needed to perform the work. Following these preparations, steps will be taken during 1981 to begin cleanup of contaminated properties in the vicinity of the processing sites at Canonsburg, Pennsylvania, and Salt Lake City, Utah.

Spent Nuclear Fuel

The Presidential nuclear waste policy statement of February 1980 reaffirmed Administration support for a limited amount of Federal spent fuel storage capacity. This capacity would provide flexibility for the waste disposal program, alternative storage for utilities unable to find other storage capacity, and storage for a limited amount of foreign spent fuel in cases where this would further nuclear non-proliferation objectives. Such storage capacity is termed "away-from-reactor" storage.

In February 1979, the Department submitted legislation to Congress that would authorize the Department to accept and take title to spent fuel from U.S. nuclear reactors as well as a limited quantity of fuel from other countries. A generic environmental impact statement supporting this policy was published in May 1980, and a record-of-decision to implement the policy was issued in July 1980. However, no spent fuel legislation was passed during the last session of Congress. Until such legislation is enacted, Federal away-from-reactor facilities for storage of spent fuel cannot be acquired or built.

In March 1980, a few months after it updated its 1979 report on away-from-reactor requirements, the Department identified three facilities being considered for Government acquisition to meet future storage needs: the General Electric Facility in Morris, Illinois; the Nuclear Fuel Services Facility in West Valley, New York; and the Allied General Nuclear Services Facility in Barnwell, South Carolina. The Department is preparing an environmental impact statement for each of these facilities, with a draft statement scheduled to be issued in the spring of 1981. This process will be followed by formal comments and public hearings before the final statement's scheduled completion in early 1982. At that time, a decision will be made on whether any of the three facilities is suitable for a Government storage facility. Assuming the enactment of enabling

legislation by that time, DOE would then seek to acquire licenses from the Nuclear Regulatory Commission and operate the storage facilities.

The spent fuel policy emphasizes that utility-provided fees must fully recover the costs of storage and disposal. The Department will continue to provide Congress with updates covering such matters as storage and disposal fee structure and progress on facility acquisition. The latest report was issued last November, and it discusses the fee methodology and updates the 1978 estimates of the fee. Based on the 1981 annual report on storage and disposal requirements, the fee is being updated in January 1981 and then adjusted annually to ensure that the Government recovers all costs. The Department plans to prepare a report in 1981 on the possible acquisition costs of existing storage capacity, along with appraisals of the facilities being considered.

The Department is continuing its evaluation of the economic and technical aspects of spent fuel storage. Two reports discussing spent fuel storage costs were issued in 1980. One report shows that new at-reactor storage basins are not as economical as away-from-reactor storage unless there are three or more reactors on a site; the other report demonstrates that, in most cases, an away-from-reactor storage system is significantly more economical than an at-reactor storage basin system.

DOE is continuing its studies of advanced storage techniques. Fuel disassembly and dry storage research is needed to maximize at-reactor and away-from-reactor storage capacities. The Department also continues to support international groups in all economic and technical areas relating to the storage of spent nuclear fuel.

Uranium Resource Assessment

The National Uranium Resource Evaluation program was established in 1974 to reduce uncertainties about the extent, availability, and economics of both domestic and foreign nuclear fuel resources. During 1980, work centered on identifying new areas with prospects for further geological exploration and developing improved technology for use in uranium resource assessment, exploration, and production.

Participants in the program include the U.S. Geological Survey, various state geologic surveys, industry, and universities. DOE's Grand Junction office

coordinates and monitors field activities. These include a nationwide aerial radiometric and hydrogeochemical survey, surface geologic studies, and drilling to obtain subsurface geologic information in critical areas. The program also undertakes thorium resource studies and participates in the International Uranium Resource Evaluation Project, which determines the potential for discovery of additional uranium resources worldwide.

As a standard reference for the surveys, the 621 United States National Topographic Map Series 1° x 2° quadrangles have been used. Aerial radiometric surveys covering 420 quadrangles and hydrogeochemical surveys covering 354 quadrangles were completed by September 30, 1980, for use in the assessment process; 60 percent of these surveys were released to the public. Resource assessment was complete for 135 quadrangles. These activities contributed to the publication of a national assessment of all the presently known reserves and many of the currently estimated potential resources of the United States. During 1981, the program will take a new direction, emphasizing a more geologically specific and selective approach to resource assessment rather than the comprehensive, systematic approach mentioned above.

DOE's uranium resource assessment program also provides annual estimates of total U.S. domestic uranium ore reserves and resources and an annual survey of uranium prices and procurements. Periodic studies of production capabilities and other supply and demand factors are undertaken to ascertain their effect on uranium resources. The program also presents a semiannual report covering all phases of the domestic uranium market—domestic sales and prices, imports, inventories, unfilled demand, and uncommitted supply.

Outlook

Today, more than 100 nuclear plants are in various stages of planning and construction in the United States. By the year 2000, these plants could be producing an additional 115,000 megawatts of electricity, thereby tripling current U.S. nuclear generating capacity of about 55,000 megawatts. With the resolution of public concerns about nuclear energy, with advances in technology, and with renewed confidence on the part of utilities, nuclear power's contribution to the Nation's energy requirements could be even larger than projected.

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Chapter 5

Renewable Energy Resources

Introduction

In the past year, the Department continued its work in four types of renewable resources: solar energy, geothermal energy, fusion, and the breeder reactor.

The following chapter covers solar, geothermal, and magnetic fusion. The other fusion option—inertial fusion—is described in the chapter on defense programs because its near-term focus is primarily on defense applications. The breeder reactor is discussed in the context of nuclear energy programs.

Solar Programs

Introduction

Over 100 years ago, the United States relied primarily on two forms of solar energy: wood for heating and steam raising, and falling water for mechanical energy. In 1859, petroleum was discovered in Pennsylvania and rapidly replaced whale oil for lighting. Meanwhile, the Nation's industries began to turn to coal. As a result, the Nation is now heavily dependent on depleting fossil fuels, while the use of wood and water power provides only about 6 percent of our solar energy needs.

As the President indicated in his Solar Energy Message of June 20, 1979, solar energy has a number of advantages over conventional fuels. A renewable resource, it provides an important hedge against the depletion of fossil fuels. Solar systems are often more cost-effective on life-cycle basis than conventional systems; they are more

environmentally acceptable, and, moreover, they create jobs.

Any national solar strategy must account for the enormous complexities of energy markets, the diversity of solar resources, regional needs, and environmental factors. It must be also responsive to rapidly changing conventional energy prices.

The range of market needs for energy services is quite broad, including high-temperature process heat, low-temperature space heat, mechanical power, electricity, fuels for transportation, and chemical feedstocks. The magnitude of these market needs varies considerably by region, as does the price and availability of competing fossil fuels. The regions also have different institutional infrastructures—another determinant of the ease with which solar technologies can penetrate the markets. Technologies are available now or being developed that employ solar resources for end-use market applications. These solar resources include direct sunlight (insolation) for both the thermal applications and electricity generation, as well as indirect resources such as biomass, hydro, wind and ocean energy.

In view of the diversity of potential markets and solar resources, there is clearly a need to support the development and assessment of a broad range of solar technologies. Figure 5-1 depicts the diversity of solar resources and possible applications.

It is emphasized that all of the solar resources have been proven. One key difference, however, is the proximity of the various technologies to economic feasibility under current market conditions. Some technologies are cost

petitive today: wood combustion for heating, passive r heating of homes, and photovoltaic electricity generation for remote locations. Other technologies are sufficiently close to cost competitiveness that the removal of market imperfections and realization of economies of large-scale production will move them into the marketplace.

The fact remains, however, that industry and the public have been slow to adopt the currently available solar technologies. The private sector will move heavily into marketing solar energy systems only when the profit incentive is strong and immediate. Currently, there are a number of economic, social, and market barriers inhibiting the adoption of solar technologies, including limited public awareness of, and confidence in, the technologies, and market pricing imperfections.

In June 1979, the President set a goal to provide 20 percent of U.S. energy consumption by solar and renewable energy sources by the year 2000. For this goal to be met, the share contributed by these energy sources will have to increase dramatically during the 1990s. Specific initiatives to speed up the use of solar energy were identified by the President:

1. Incremental cost pricing of natural gas.
2. Review of electricity pricing policies.
3. Deregulation of domestic gas and oil prices.
4. Establishment of a solar energy development bank.
5. Exemption of gasohol from Federal gasoline taxes.
6. Introduction of a variety of tax credits favoring use of renewables.

As stated in the President's Solar Message, the Federal government provides incentives, information, and the impetus for the over all solar effort. Federal action is based on the following guiding principles:

1. The Government should not play the predominant role in solar over the long term. Federal programs should leverage participation by the private sector.
2. The Federal government should transfer the key role to the private sector as soon as possible.
3. Financing incentives should be used to accelerate adoption of solar systems.
4. Federal regulation should be minimized.
5. Social goals should not be hindered by development of solar energy.

Accordingly, the current strategy is sharply focused on three major areas:

1. Providing incentives and information, and removing barriers to technologies that are cost-effective or nearly so. These technologies include wood combustion, passive design, active hot water systems, alcohol fuels, and small-scale hydro.
2. Stimulating cost reduction for technologies that can

make significant contributions in the near-to mid-term (prior to 1990); for example, solar space heating, wind systems, agricultural and industrial process heat, biomass, and photovoltaics.

3. Developing technologies with significant long-term potential, including ocean systems, biomass plantations (aquatic and terrestrial), and solar thermal.

The fundamental difficulty in the development of solar energy use is the diversity of its resources and applications. In contrast to conventional systems, widespread use of solar energy requires implementation by millions of decision-makers.

A number of developments in 1980 significantly increased the likelihood that decision-makers would consider and adopt solar systems. For example, the Crude Oil Windfall Profits Tax Act (P.L. 96-233) extended the waiver of the Federal tax on gasohol (4 cents per gallon) until 1992 and significantly increased tax credits for residential, commercial, and industrial solar energy use. As examples of the latter, the maximum residential solar credit increased from \$2,200 to \$4,000; and an industrial solar energy credit of 15 percent, in addition to the permanent 10 percent investment tax credit, was provided.

Another significant development was the Energy Security Act (P.L. 96-294) signed by the President on June 30, 1980. The act established a Synthetic Fuels Corporation with a production capacity goal of 500,000 barrels per day by 1990. Liquid and gaseous fuels from biomass are covered under the Synthetic Fuels Corporation, although the bulk of production is expected to come from coal and oil shale. In addition, it created the Solar Energy and Energy Conservation Bank in the Department of Housing and Urban Development, a major component of the President's solar energy message, to provide low-interest loans for residential applications of solar energy.

Evidence of an increased national interest in biomass and alcohol fuels is the response to solicitation under the Alternative Fuels Production Program (amendments to the Defense Production Act, P.L. 96-126). This program appropriated \$2.2 billion for synthetic fuels projects; in the first solicitation for feasibility studies, 600 of 863 proposals were for biomass and alcohol fuels.

Solar Applications for Buildings

The intrinsic diffuseness of the buildings sector complicates the adoption of new ideas and products. It is a market typified by a multitude of vendors, potential customers, and intermediaries between producer and ultimate consumer. There are tens of millions of separate residential units; for example, 54 million single-family homes. In addition, there are several million office buildings,

warehouses, wholesale and retail outlets, hotels and motels, schools, hospitals and many other public buildings.

The infrastructure servicing these customers is equally diffuse. There are over 100,000 homebuilders in this country. Most build homes in a single city or country. The vast majority build in the neighborhood of 20 units annually; the "big five" U.S. homebuilders account for only 2.4 percent of annual production. In addition, there are over 60,000 architects; 200,000 civil, electrical and mechanical engineers; and 2 million craftsmen in the building industry. Finally, there are thousands of mortgage lenders and real-estate appraisers, and multitudes of inspectors in over 3,100 different building code jurisdictions in the country.

The Department's solar building sector program is organized in terms of three major technological approaches: active heating and cooling; passive and hybrid systems; and photovoltaics. R&D of other relevant technologies such as wind, wood, and solar thermal are managed in other offices, with coordination provided to the Office of Solar Applications for Buildings.

Active Heating and Cooling: Created in 1974 by the Solar Heating and Cooling Demonstration Act, the active heating and cooling program was designed to underwrite the initial risk of the private sector in a new industry, to provide "hands-on" experience for architects, engineers and craftsmen, and to provide information to the general public. Initially, emphasis was placed on developing and demonstrating active solar products over a 5-year period. Four major DOE solicitations resulted in the funding of 303 commercial demonstration projects. In cooperation with HUD, a residential demonstration program was carried out with 700 residential projects involving over 12,000 dwelling units. In that 5-year period, the industry moved from custom-designed systems using a variety of components to sales of packaged systems. The advantage of the latter is that they permit prior testing and development of marketable systems, resulting in an improved product for the consumer.

In the area of solar heating, direct gain (passive) space heating and active hot water systems offer the best near-term potential for consumer acceptance. Approximately 150,000 active systems have been installed, mostly for providing hot water. About 5,000 dealers are currently offering solar systems. Active systems are eligible for the 40 percent Federal tax credit, and numerous state and local incentives are also provided. During 1980, an integrated gas/solar hot water system was developed within the DOE program in addition to collector component developments. The latter resulted in higher collector performance and longer-life glazing materials.

Active space heating systems require further development, and a number of projects were sponsored in 1980.

Primary emphasis in 1981 will be on resolving technical problems associated with corrosion, controls and freezing. The correction of these problems should lead to a product offering the purchaser both dependability and economy.

The solar technology for space cooling is less developed than the one for solar heating because it requires mechanical or high temperature thermal energy to drive the cooling process. Fewer than 100 systems are in operation. Much of the research activity is centered around development of bench scale and prototypes of solar-driven conventional air conditional systems.

Testing and installation of prototypical residential and commercial Rankine and absorption units were completed in 1980. Design and prototype tests of a residential-sized desiccant cooling unit were completed. The space cooling activities for 1981 will basically continue those activities started in 1980, and support industrial participation in and development of commercially viable residential and commercial systems.

In 1980, the Solar Federal Buildings Program awarded \$31 million to 16 Federal agencies for the design, construction and monitoring of 843 solar projects. The data collected from these projects is conveyed to the general public and the solar industry and should act as a further stimulus to private sector activity.

Passive and Hybrid: Passive solar buildings employ designs and products that rely on natural processes of energy transfer such as conduction, convection and radiation. When other solar technologies such as active systems and photovoltaics are also integrated, the result is a hybrid solar application. Passive techniques include greenhouses, sunspaces, thermal storage walls, and the proper orientation of windows and living spaces.

For thousands of years, people have used the Sun to heat their homes. Cities in ancient Greece and Asia Minor utilized passive solar principles in urban planning and in building design. Furthermore, the Roman Empire established solar access laws to guarantee a person's right to unobstructed sunlight. Notwithstanding the resurgence of interest in the benefits of passive solar design, this proven approach is beset by a number of barriers. The public and industry lack information. Data needed to evaluate the thermal and economic performance of passive products and buildings are inadequate. And, institutional factors such as building codes, zoning regulations, land use, and urban planning can and do prevent market penetration.

A wide variety of Federal programs are designed to overcome these barriers. The passive solar residential buildings program is a two-pronged effort aimed at developing cost-competitive passive solar heating designs and systems for new and existing residential buildings, and conducting R&D of passive residential cooling technologies. In a joint program between DOE and HUD durin-

1980, some 350 passive residential demonstrations were completed and construction. Designs were completed and test marketing began for 20 single-family and multi-family buildings. A pre-fabricated buildings program was initiated and designs were completed for 25 different types of manufactured buildings.

The passive commercial buildings program has three concerns. The first is to develop cost-competitive passive solar heating technology for commercial buildings, the second to conduct R&D of passive commercial cooling technologies; and the third to undertake research and design on passive daylighting systems used in commercial buildings. Thirty-three commercial building prototypes were designed last year.

A passive products program, whose objective is to adapt and refine traditional building materials for use in new and retrofit passive systems, researches, develops, and tests, new products that can solve engineering problems unique to passive design. In 1980, seven solar products were field tested and 22 marketable products initiated for movable insulation, sunspace, and glazing materials.

For the passive and hybrid solar program, 1981 promises to be a year marked by increased marketplace entry of proven solar energy systems, reflecting the program's progress in accelerating development of passive technologies and designs. Approximately 56,000 residential installations, 300,000 square feet of commercial space, and \$36 million in sales are projected for 1981. Construction is scheduled to begin on 33 commercial prototype buildings. At the same time, performance and user data from six highly instrumented residences, 70 low-level monitored residences, and 400 homeowners will be collected, analyzed, and disseminated. Additionally, a thousand agriculture installations and pilot projects will be carried out in the four regional solar center areas.

Marketing analysis and surveys will be conducted to determine builder and consumer attitudes towards various products and designs. Market development activities based on successful tests of greenhouse and farm shelter heating as well as other rural building applications will be emphasized. An extensive program of training, information, dissemination, education, and economic and market analysis will be carried out to promote passive and hybrid market penetration.

Photovoltaics: Photovoltaic devices, or solar cells, convert light directly into electricity. When light strikes materials called semiconductors, internal voltages can be created. Attached wires can draw off electricity. The resulting systems may be built in a wide range of sizes and for many uses. Although there is ample room for improvement, the basic technology is well understood. The major objective, however, is to lower costs to make photovoltaics competitive with present energy sources. The goals of the

Department's program are to reduce installed system costs to a range of \$6 to \$13 per watt (in 1980 dollars) in the near future, and to about \$2 per watt by the mid-1980's.

A vigorous partnership between Government and industry is expected to yield further cost reduction by stimulating industrial innovation. This, in turn, should lead to competitive solar cell power in the mid-1980's for residential applications, commercial buildings, and in some cases, central power stations. The development of advanced materials and large automated production facilities should make it possible to attain still further price reduction by 1990, perhaps to \$1 per peak watt for central power station applications.

The Department of Energy Act of 1978, P.L. 95-238, Section 208 authorized the purchase of life-cycle, cost-effective photovoltaic systems for Federal facilities. That program was greatly augmented by the establishment of the Federal Photovoltaic Utilization Program (FPUP) under Title V, Part 4, of the National Energy Conservation Policy Act (P.L. 95-619), which authorized additional purchases of photovoltaic systems for use by Federal agencies between 1979 and 1981. A total of \$32 million was actually appropriated for this program under the two authorizations.

As indicated in the act, the key objectives of the Federal program are:

1. To accelerate the growth of a commercially viable and cooperative industry to make photovoltaic solar electric systems available to the general public as an option in order to reduce national consumption of fossil fuel.
2. To reduce fossil fuel costs to the Federal Government.
3. To stimulate the general use within the Federal Government of methods for minimizing life-cycle costs
4. To develop performance data on the program.

To achieve the objectives established by Congress, the program must stimulate industry and market development. The strategy to date has been to support applications identified as having significant market potential in the private domestic arena, in foreign countries, and in Federal agencies.

The program was conducted in four funding cycles, as summarized in Table 5-1.

In all, the program has funded approximately 3,000 photovoltaic systems to be used by participating agencies in 45 states. There are also applications in the West Indies, the Pacific Islands and West Africa. The first three cycles under FPUP funded small power systems to provide solar electricity for such applications as telecommunications, water pumping and navigation aids in remote locations. Cycle IV approved seven grid-connected buildings applica-

Table 5-1.—Application cycles of the Federal photovoltaics utilization program

<i>Year</i>	<i>Cycle</i>	<i>Major applications</i>	<i>Cost effective</i>
1978	I	Small remote	Now
1979	II	Small remote	Early 1980's
	III	Intermediate remote	
1980	IV	Intermediate and residential	Mid 1980's on

tions for Federal schools, office buildings, residences, and a U.S. embassy building in Senegal.

The most significant recent accomplishments have been in the area of reducing the cost of photovoltaic systems. Several systems have been installed around the country, including a photovoltaic-powered Indian village in Arizona, an irrigation system for eighty acres in Nebraska, power for a residential and visitor complex at a National Monument Park in Utah, a large power system for a remote radar site in Southern California, a commercial radio station in Ohio, and the first photovoltaic (with grid back-up) residence in Phoenix, Arizona. Remote applications now power forestry lookout towers, ocean buoys, highway signs, and mobile communications equipment. A program for using photovoltaic systems on Federal sites is now underway.

1981 plans call for continuing design and construction of 13 projects from 20 to 350 peak kilowatts. At least 10 projects are scheduled to be completed between January and September 1981, including schools, a hospital, a shopping center, an office building, and two airport buildings. Also, by the end of 1981, approximately 20 experimental photovoltaic residences are to become operational.

Applications for Industry

The industrial sector now accounts for about 25 percent of total U.S. energy consumption; this figure is estimated to increase to 34 percent by 1995. In terms of end-use, industrial demand for energy is heavily weighted toward heat: about two-thirds is needed to generate heat for industrial processes, and about one-third is used as electricity.

Almost all process heat required by industry is generated internally, while a large portion of electrical needs is provided by central utilities. Those concerns that do generate their own electricity are moving toward cogeneration systems, using the waste heat of electric generation

systems to meet thermal needs. The solar options best suited for industrial applications, then, are those which can generate thermal energy, for either cogeneration or industrial process heat systems. The technologies which can do this are solar thermal and biomass.

To spur development of the overall solar industrial market, a market research and integration effort was established in 1980. Key activities involve the development of a market strategy, assessment of barriers and incentives, and interaction with potential users. The market strategy outlines an action plan for accelerating development of those solar technologies best suited to specific industrial sectors. The first step in developing the strategy involved gathering data for an initial screening of industrial energy use. Barriers and incentives analysis is addressing the problems of alternative financing methods and the need for incentives, and laying the groundwork for new legislation.

A major 1980 accomplishment involved a review of legislation affecting solar applications in the industrial sector. The bulk of the solar legislation has concentrated on general R&D and deployment of systems for residential and large, centralized applications. Legislation applicable to the industrial sector includes the tax credit provisions of the Energy Tax Act of 1978 (P.L. 95-618), and the Crude Oil Windfall Profit Tax Act of 1980 (P.L. 96-223); the Small Business Energy Loan Act (P.L. 95-315); the Powerplant and Industrial Fuel Use Act of 1978 (P.L. 95-620); and the Solar Energy and Energy Conservation Bank set up under the Energy Security Act of 1980 (P.L. 96-294).

The key effort in 1981 will be to continue to evaluate solar incentives and methods of financing the installation of solar systems. Alternative financing methods, such as leverage leasing and limited partnerships, will also be studied. Existing and potential Federal and state incentives, including tax credits, accelerated depreciation, loans, and loan guarantees, will be further analyzed to determine their effects on the economic feasibility, market penetration, and the need for new legislation.

1981 plans call for conducting site-specific assessments to determine the potential of the various solar technologies for specific industries. Sensitivity analyses will be made for various conventional energy costs, methods of financing, and existing and potential incentives. This data will help determine the impact and need for various types of legislation.

Solar Thermal Energy Systems

The three principal types of solar thermal systems under development collect and concentrate the Sun's rays in different ways. The central receiver system shown in Figure 5-2 uses a large number of heliostats, each of which tracks the Sun through the sky, and concentrates the radiant energy on a single tower or central receiver.

Figure 5-2
Central receiver, solar thermal power system

Parabolic troughs concentrate energy along a line at the focus of the trough, and are classified as linear collectors. The parabolic dish, the third collector type, is more like an individual heliostat with a collector or heat engine mounted at the focus. Potential applications for these systems include providing heat and electric power to utilities, industry, and small communities.

During the course of this past year, it became apparent that solar thermal technology is sufficiently well developed to permit design and commercial operation of central receiver and parabolic trough solar thermal systems. Consequently, the program is now concentrating on stimulating near-term market opportunities in utility and industry repowering for central receiver systems, and solar-enhanced oil recovery for parabolic trough systems. Repowering is the conversion of an existing gas or oil fired boiler at a power plant or industrial site to use steam produced from the central receiver system, while the conventional fuel is used as a backup on cloudy days. Repowering, thus, obviates the need for energy storage.

Solar-enhanced oil recovery is attractive in Southern California at present, because retracted oil is burned to produce the steam necessary to extract more oil. This causes a loss of about one-third of the oil being pumped out of the ground. Environmental concerns preclude burning coal as an alternative. Consequently, the relatively high cost of this early solar system is not a deterrent to its use in this application.

Construction of a pilot 10-megawatt, central receiver generating plant was begun in 1980 near Barstow, California. Jointly funded by DOE, the Southern California Edison Company and the City of Los Angeles Department of Water and Power, this facility will be the first complete operational test of a solar thermal system. (For a fuller—and illustrated—discussion of this project, see Volume III, *Project Summaries*, of this report, pp. 50-51).

Fourteen conceptual cost-shared design studies conducted in the period 1978-1980 examined the ability of central receiver technology to displace oil and natural gas in both electric utility thermal power plants and industrial facilities using high-temperature process heat. The selection of projects for preliminary design, detailed design and construction is scheduled for 1981. It is planned to begin construction in 1982 with completion planned for 1985. Eight of the 14 studies are for electric utility repowering of existing oil or natural gas generating plans. The other six are the first site-specific studies of solar central receiver systems for industrial process heat.

The repowering projects selected for construction in 1982 should give industry hands-on experience in actual industrial settings and create demand for design and fabrication of components (receivers, heliostats, and storage). The projects are also expected to yield data on acquisition costs, operating and maintenance costs, and reliability for other interested, privately funded commercial users.

The parabolic trough systems are the solar thermal system closest to commercial readiness. Thus far, the Department has sponsored three irrigation projects in Willard, New Mexico; Coolidge, Arizona; and Gila Bend, Arizona, as well as eight operational industrial process heat projects for fabric drying, gauze bleaching, commercial laundry, fruit juice processing, latex production, oil refining, beer brewing and potato frying.

To insure the successful commercialization of an expanding trough industry, a modular industrial solar retrofit project was designed in 1980 to minimize one-of-a-kind or site-tailored engineering associated with each solar thermal application. The project incorporates modular parabolic trough systems which can be used singularly or in multiple units to provide the solar equivalent of package boilers. System design and hardware will be tested and qualified at the mid-temperature solar system test facility in Albuquerque, New Mexico, and qualified systems will be selected by industrial users. This activity is scheduled for 1981. The design verification and site team selection of suppliers, designers and users is scheduled to begin in 1982. Construction should be initiated in 1983. Up to 10 industrial users will be involved in each of three cycles. An evaluation phase will follow each cycle before the next cycle begins.

Among the many candidates for industrial application, solar enhanced oil recovery is the most visible and promising near-term market opportunity. Solar thermal steam, rather than oil-fired steam will extract additional oil from producing wells. California, where environmental controls are especially strict, is a major potential user of this environmentally-benign solar thermal application. Construction is scheduled for 1982.

Parabolic dish systems are less mature technologically than central receiver and linear systems, but they promise significant solar thermal payoff. Their advantage lies in greater efficiency, modularity, and relatively high temperatures, however, capital costs must be reduced considerably. Currently under construction the first parabolic dish project is a total energy system at an existing knitwear factory at Shenandoah, Georgia. This 400 kilowatt electric, 2.6 megawatt thermal project is scheduled to begin operation in late 1981.

Biomass Energy Systems

An energy resource consisting of plant and animal organic matter, biomass is both abundant and renewable. Although the term "biomass" is relatively new, using biomass for energy is not a new idea. Only a century ago, biomass in the form of wood met 90 percent of domestic needs. Today, biomass supplies about 2 percent of U.S. energy needs, mostly through the use of wood. Yet, there is evidence that this percentage is beginning to increase: in

1979, 1 million wood stoves were purchased in the U.S.; during the winter of 1979-1980, New Englanders—who have traditionally derived a large part of their energy needs from wood—burned the equivalent of 6.5 million gallons of home heating oil. In addition, the forest products industry now obtains over 50 percent of its energy needs from wood. DOE's goal is to accelerate further this trend so that as early as 1985—and certainly by the year 2000—biomass will make a substantial contribution to domestic energy supplies.

As Figure 5-3 shows, raw materials, energy conversion technologies, products, and end-use markets of biomass are extremely diverse and versatile. For example, wood and wood residues, agricultural wastes, arid land plant species, and aquatic plants can be converted into heat, gas, oil and chemicals for use in private residences, utilities, and industry.

Much of the nation has abundant forest resources, as seen in Figure 5-4, and, in most of the areas that do not, cropland and agricultural waste is available. Because wood is the most promising and abundant biomass resource, near term efforts in developing biomass energy systems are designed to maximize wood energy use. Wood has the potential to contribute up to 3 quads of energy by 1985—a doubling of current use. To ensure that this level will be reached, outreach and education programs are vital. Accordingly, a wood energy technical assistance team and an information network have been established in the northeast to aid in the commercialization of wood energy. Plans are to expand these concepts to other regions in the near future.

Despite wood's promise, many potential users are reluctant to convert to wood because of concern for a reliable supply. In an effort to improve the availability of wood for energy, the Department has successfully field-tested a mobile clear-cutting tree harvester. In addition, DOE is testing methods of increasing wood production; the planting of 190 acres of a eucalyptus silviculture test plantation in Hawaii is the first step in an attempt to grow wood more quickly and productively.

Like wood, agricultural wastes have near-term application for energy production, and the commercialization of wastes from agricultural energy can be seen as the first step toward energy self-sufficiency for farmers. During the past year, a large-scale anaerobic digester continued operation in Bartow, Florida. Using manure from a cattle feedlot, the digester produced methane to help operate the nearby meat processing plant. At another site, an experimental, small-scale anaerobic digestion unit has been built and operated on a dairy farm, demonstrating its economic competitiveness with propane or fuel oil.

Parallel to these activities, DOE is also exploring new and more efficient methods of biomass conversion to

Figure 5-3
Scope of markets and applications for products from biomass resources

Figure 5-4
Forestland and cropland as a percentage of total land area

energy. Novel conversion techniques include deriving oil from wood, producing medium-Btu gas from wood using fluidized-bed gasification techniques without the addition of oxygen, and direct-fire combustion of green wood. The direct fire combustor is designed to obtain the same heat release rates as oil and gas-fired units. The Department is also working to ensure that biomass resources will be available to meet increasing demand. Aquatic plants, such as microalgae cattails, and arid land plants, such as gopher wood and *mesquite* may provide additional energy sources in the mid-to long-term.

During the coming year, DOE plans to accelerate the use of wood and agricultural wastes and to complete regional wood resource and market assessments to determine supply and potential demand for wood energy in specific areas. In addition, demonstration units will be installed to test low-Btu gasification for electrical power, on-farm direct combustion, low-Btu gasification of crop residues, and anaerobic digestion of cattle manure. It is hoped that the industrial and utility sectors will follow the lead of the residential and agricultural sectors and increase the amount of energy derived from biomass to at least 3 quads by 1985.

Activities designed to increase biomass production and its conversion include the screening of productive woody, herbaceous, and aquatic species, and the development and testing of cost-effective harvesting systems. Production efforts are designed to ensure a continuous and reliable biomass supply for the future. Planned conversion activities include the design of small-scale, low-cost Btu gasification units and the characterization of biocrude oil from liquefaction. The Department hopes that continued improvement in the efficiency of such facilities will make them a viable alternative to conventional conversion facilities.

Finally, programs having little or no immediate impact, but that could be important energy contributors by the year 2000 and beyond, are being planned and developed. Research will continue in biological hydrogen production and in the production of hydrocarbon-bearing plants, such as milkweed and *Euphorbia*. In addition, a program to develop petrochemical substitutes from biomass is being initiated. It is possible that breakthroughs in one or more of these technologies could accelerate their use.

The biomass program is in a position to become one of the most important contributors to alternative energy technologies in years to come. There is clearly an expanding base of interest in the residential sector, and recent legislation, such as the Alternative Fuels Act and the Energy Security Act, is providing additional impetus.

Just how much energy biomass will contribute by the year 2000 remains uncertain; estimates range from between

6 and 17 quads. But, of one thing we can be sure: biomass promises to yield by far the largest portion of the 20 percent solar goals for the end of the century.

Alcohol Fuels

Over one-half of the liquid fuels currently consumed in the U.S. is used in transportation, and about three-quarters of transportation fuel is in the form of gasoline used in automobiles. For some time, it has been apparent that alcohol fuels represent an attractive, renewable substitute for increasingly more expensive and scarce petroleum products. Indeed, the past 2 years have witnessed growing and widespread support and enthusiasm for alcohol fuels.

Under the Energy Tax Act of 1978, alcohol-gasoline blends were exempted from the 4 cent per gallon Federal motor fuel excise taxes until October 1, 1984. The Crude Oil Windfall Profit Tax Act signed into law on April 2, 1980, contained several provisions affecting producers, blenders, sellers, and users of alcohol fuels. These include:

1. Continuation through 1992 of the existing exemption from the four cent per gallon Federal excise taxes for alcohol-gasoline blends containing at least 10 percent alcohol.
2. Refunds for excise taxes paid on gasoline blended with at least 10 percent alcohol.
3. New income tax credits for blenders of alcohol-gasoline blends, and for users of straight alcohol fuel.
4. Continuation through 1985 of the Energy Investment Tax Credit for alcohol fuel production equipment.
5. Tax-exempt status for certain industrial development bonds for financing alcohol fuel production facilities.

Signed into law on June 30, 1980, the Energy Security Act contains additional provisions favoring alcohol fuels. Among other things, the act provided \$472.5 million from DOE for the 2-year period beginning October 1, 1980, for loan guarantees, price guarantees, and purchase agreements to plants that produce biomass-derived fuel. An equivalent amount was made available to the Department of Agriculture. The act also provided for an Office of Alcohol Fuels reporting directly to the Secretary of Energy.

By late October, the office had closed its first round of loan guarantee solicitations. Fifty-seven proposals were received of which seven were selected for negotiations leading to conditional commitments. Another activity was the establishment of the Solar Energy Research Institute's National Alcohol Fuels Information Center and Data Base, now providing both general and technical information to industry and the public. Recognizing that alcohol fuels production will require state and local programs to

encourage development and commercialization, the Office of Alcohol Fuels also conducted cooperative statewide feasibility studies in four states and is developing a model state alcohol fuels plan.

Finally, a number of technology development programs were launched or continued during the year. They include:

1. Construction of a 25-gallon-per-hour, small-scale alcohol fuel plant at the Idaho National Engineering laboratory. This project is designed to provide design, construction, and operating experience to allow the rural community and small industries to build plants and to produce fuel grade ethanol from fermentable feedstocks.
2. Assistance to the Tennessee Valley Authority to demonstrate small stills in its region.
3. The continuation of programs to develop automotive engines that operate on straight alcohol.

Solar Applications for Power

During 1980, electric utilities in the United States consumed approximately 30 percent of all the energy used. Particularly noteworthy was the utility sector's petroleum consumption. Over 1.7 million barrels per day were used by utilities—the equivalent of 30 percent of all U.S. oil imports.

The prospect of rising oil prices, supply interruptions, environmental concerns for coal-burning facilities, and recently enacted solar incentive legislation, makes several forms of solar power potentially attractive alternatives for utilities. Currently, hydropower provides roughly 10 percent of the Nation's electric energy, and several small wood or bagasse-fired units are now operating. With the exception of hydropower and wood, the principle detriments to wide scale use of solar systems for power generation are the immature state of technology development and the projected costs.

In 1980, an Office of Solar Power Applications was formed to provide a consistent approach to analysis and development of solar systems for the power sector. In addition, technology development programs in wind and ocean systems are located in this office. During its first year, the office prepared the initial draft of a market strategy document. When completed, the document will identify barriers to commercialization, early market opportunities and solar applications with major market potential. In addition, the strategy will give clear direction to program activities by outlining both a general strategy for market penetration and a specific action plan for each solar technology.

Financial incentives will also receive special attention the coming years. The office will review the disadvan-

tages of existing incentives and, if appropriate, propose incentives for utility users of solar power systems. And another area of emphasis will be on needed institutional changes. Working closely with FERC and state utility commissions, the office will consider a set of institutional actions to reduce financial risks to utilities investing in solar power technology. Some of the alternatives to be considered include rate base surcharges to finance new technologies, accelerated licensing, and timely rate base inclusion of alternative energy investments. While the office has no authority to implement these changes, it can provide information and assist in evaluating alternatives.

Man's use of wind systems is as old as civilization itself. As recently as the turn of the century, such systems were widely used to generate electric power. However, in the 1930's with the advent of inexpensive and reliable electric power from the Rural Electrification Administration, the use of these systems declined. The subsequent availability of low-cost fossil fuel accelerated this decline—a process reversed by the energy crisis in the 1970's.

Today, wind power once again promises to play a prominent role in providing essential energy. Large-scale systems are expected to compete first for use by utilities that are heavily dependent on oil, and also in areas with a large hydroelectric capability, where the conventional system can serve as a backup. As the costs of wind turbines are reduced through mass production and advanced designs, and as capital and fuel costs escalate, wind systems are expected to penetrate oil and nuclear markets. Intermediate-scale systems will be competitive for onsite use by industry or small utilities at roughly the same costs. At oil costs of \$30 per barrel, fuel costs of 5 cents per kilowatt-hour are now common in utilities heavily dependent on oil.

The principal competition for small-scale, onsite wind systems is in utility-generated electricity where initial competitiveness is dependent on local cost of power, the rate structure (including utility fuel costs), block rate structure, and any demand charges to cover the cost of providing power when the wind system cannot meet instantaneous user demands. A market for small wind systems is projected for remote applications at an energy cost of 6 to 10 cents per kilowatt-hour.

A major event in 1980 was the passage of the Wind Energy Systems Act of 1980 (P.L. 96-345), setting a goal of the installation of 800 megawatts of wind-generating capacity by 1988, with at least 100 megawatts provided by small systems. The law authorizes Federal assistance through loans, grants, and purchases to stimulate wind systems development. It also calls for a new wind resource assessment program.

The Department is sponsoring development and testing of small, intermediate and large machines. In 1980,

eight advanced small machine prototypes in three size classifications (1 to 2, 9, and 40 kilowatts) were installed at the Rocky Flats test site. Testing was also conducted on 16 commercially available machines. In 1981, 15 new commercial machines are scheduled to be tested, as will a 17-meter Darrieus and five new advanced prototypes.

In 1980, the field evaluation program was initiated in order to provide experience in siting and interconnecting small machines with the utility grid. Currently, 20 machines have been installed, 45 states are participating, and over 10,000 inquiries from potential users and suppliers have been received.

State energy offices, as well as utilities, are enthusiastic about this effort, which is the first large-scale evaluation of commercially available machines. The early results have identified the need for reliability and performance improvements, and especially the need for an effective supplier infrastructure.

For intermediate size machines, a fourth, and final, MOD-OA was installed at Kakuku Point, Hawaii. Building on the experience of the three earlier MOD-OAs, the performance of this intermediate-scale 200 kilowatt machine has been outstanding. Dedicated on July 3, 1980, this unit has operated over 2,000 of a possible 2,500 hours. Taking advantage of the favorable trade winds, this represented over 90 percent of the time that the threshold wind speed was available. Over 300 megawatt-hours were produced and the average power level has been 158 kilowatts. The other three MOD-OAs at Clayton, New Mexico; Culebra, Puerto Rico; and Block Island, Rhode Island, have operated 8,070, 2,080, and 1,555 hours, respectively.

The first DOE-sponsored large machine, the MOD-1, was installed in Boone, North Carolina in July 1979. Noise and television interference problems cropped up during initial operation. In 1980, significant findings were made on how to avoid noise. Important characteristics include the tower, the terrain, and the local environment.

The major event of 1981 will be the dedication of the MOD-2 minicluster. Three 2.5 megawatt machines are being installed near Goodnoe Hills, Washington to provide the first data on how machines will operate in a cluster, or wind farm arrangement. The output of the machines will be integrated into the Booneville Power Administration utility grid. It is planned to publish a national atlas of the wind resource in 1981, paving the way for future siting studies.

Other key events anticipated for 1981 are the initiation of a reliability improvement program for small machines, the development of plans to meet the requirements of the Wind Energy Systems Act and the continued development of the MOD-5 and MOD-6 horizontal and vertical axis machines. These latter items represent the next and final Department-developed generation of large and intermediate scale machines.

Ocean Energy Systems

The world's oceans are vast solar collectors absorbing energy from the Sun and the wind. Although only a tiny portion of this energy is recoverable, the potential resource is enormous. Currently, the Department of Energy is exploring four potential sources of ocean energy: ocean thermal energy conversion (OTEC), wave energy systems, ocean current systems, and differences in the salinity of ocean waters.

OTEC uses the temperature difference between warm surface water and cold deep ocean water to operate heat engines that can produce electricity. These temperature differences are particularly pronounced in tropical waters and OTEC technology, therefore, has particular relevance to the energy needs of U.S. islands (e.g., Hawaii, Puerto Rico, Virgin Islands, Guam) subject to high-cost foreign fuels, interdiction and embargo.

Of the four potential sources, thermal gradients seem to offer the best prospect of commercialization in the near future. In fact, an OTEC experiment was conducted on an island off the coast of Cuba as long ago as 1929. This concept uses two power cycles: the closed cycle, which uses a fluid with a low boiling point such as ammonia, and the open cycle, which uses seawater as the working fluid. Promising options for applying OTEC involve moored platforms that supply electricity by submarine cable to submarine shore, and floating platforms that "graze" for optimum temperature differences while generating electricity for on-board processing of energy-intensive products.

Two recently passed laws have significantly shaped the OTEC program by shifting the emphasis away from basic R&D toward the commercialization of existing technology. The Ocean Thermal Energy Conversion, Research, Development and Demonstration Act (P.L. 96-310) established several goals for OTEC between 1985 and 2000, the most important of which is a national target of 10,000 megawatts of OTEC power-generating capacity by 1999. The Ocean Thermal Energy Conservation Act (P.L. 96-320), meanwhile, attempts to facilitate commercialization by establishing a one-step licensing procedure for OTEC units and by authorizing \$2 billion in loan guarantees for the construction of OTEC powerplants.

A number of studies have found that OTEC systems could be cost-effective for base-load power markets in island locations such as Hawaii and Puerto Rico by the mid-1980's. The studies also concluded that with further technology development, OTEC systems could compete for portions of the mainland U.S. electricity market as well as the market to produce certain energy-intensive fuels and chemicals (e.g., hydrogen and ammonia).

A number of engineering challenges must be resolved to permit cost-effective OTEC operation. First, the cost and performance of heat exchangers must be substantial

Figure 5-5—OTEC-1 test configuration

improved over existing practice since the ocean temperature differential is only 30 to 40°F, necessitating a very large and efficient heat exchanger. Formation of algae and scaling reduces efficiency, and consequently a means of keeping the exchanger clean is needed. In addition, a 2,000 to 3,000-foot pipe to bring the cold water from the ocean depths represents a significant engineering challenge. Lastly, an electric cable system must be developed to survive the rigors of the deep sea environment.

In 1980, a 10-kilowatt "mini" OTEC plant started off the coast of Hawaii. This plant was, in fact, the first operation of a complete OTEC system and showed that electric power could be produced using a fairly low temperature differential in ocean waters. It enhanced the commercial appeal of ocean thermal technology because it was completely funded by private industry and the state of Hawaii.

Although mini-OTEC is operating on only a small scale, larger facilities are being considered. During 1980, a solicitation was issued for the conceptual design of a 40-megawatt pilot plant, which is to demonstrate that ocean thermal technology can generate electricity on a fairly large scale and integrate this power into existing utility grids. The 40-megawatt plant would reduce the uncertainty surrounding OTEC technology by providing data on operating efficiency, durability of key subsystems, operation, and maintenance to permit scale-up to the economies of commercial plants.

Key intermediate data on performance of heat exchangers and other components will be provided by

OTEC-1, a floating test facility using a tanker converted during 1980 into a sea-based laboratory to test key OTEC subsystems. OTEC-1, viewed in Figure 5-5, is now deployed off the coast of Hawaii.

Substantial progress is expected during 1981 in solving the problem of keeping heat exchangers clean. OTEC-1 will test a titanium shell/tube heat exchanger 55 feet long and 15 feet in diameter. To clean the heat exchangers, OTEC-1 will use a chlorination/Amertap system. Widely used in conventional heat exchangers, it shows a great deal of promise for the prevention of biofouling. Additionally, in 1981, OTEC-1 is scheduled to test a fully instrumented cold water pipe and also to monitor system effluents to aid in future environmental assessments of OTEC technology.

Substantial progress should be made in 1981 in resolving the issues associated with the structural integrity of cold water pipes and transmission cables. A one-third scale test of cold water pipes will be conducted at sea and is intended, among other things, to validate existing design tools for the cold water pipe subsystem. Meanwhile, tests are to be conducted on land of promising power cable designs to assess the electrical and mechanical load capabilities of different riser power cable systems.

During the next year, the Department plans to complete the comprehensive management plan mandated by the Ocean Thermal Energy Conversion RD&D Act. This plan will be a detailed, fully integrated strategy to attain the goal of establishing 10,000 megawatts of OTEC capacity by 1999. It will outline the objective of all RD&D, set

Figure 5-6—Preliminary permit applications for hydropower developments (≤ 30 MW)

out program and management strategies, and present a 5-year schedule of projected accomplishments along with projections of budgetary requirements.

Wave energy systems extract mechanical energy from waves and convert it to electricity. Wave energy is available from most of the waters within 25 miles of the U.S. mainland.

In ocean current systems, water turbines that resemble windmills are used to convert the kinetic energy in currents to electricity. Although the potential recoverable resource is much less than that for OTEC or wave energy, current systems could be very useful in specific locations—e.g., off the coast of Florida in the Gulf Stream.

Differences in the salinity of ocean waters or any two saltwater solutions, can, theoretically, be used to produce energy. The Department is investigating the technical feasibility of various approaches to exploiting salinity gradients.

Exploratory development and testing is scheduled for all three of the above systems during the years ahead to determine what contributions they can make in the future.

Hydropower

A clean, safe and proven energy source, hydropower is used extensively in the West, the Northeast, and the Tennessee River Valley. Over the years, the rate of hydropower development and its contribution to total energy requirements have declined due to the relative costs of other forms of electricity and other factors. This trend may, however, reverse in the face of rising costs of oil and concern over the fuel's secure availability. Evidence of change is seen in the increase in the number of applications to the Federal Energy Regulatory Commission for preliminary permits; see Figure 5-6. (It is too early to determine how many of the proposals will, in fact, become actual developments.) Hydropower and biomass together are expected to constitute about one-half of the national goal to provide 20 percent of domestic energy needs in 2000 from solar and other renewable energy sources.

Small-scale hydropower plants offer several advantages: they utilize a renewable resource—flowing water; they are virtually nonpolluting; and they are small and

ethetically acceptable. Moreover, the effects upon dam ecology are minor compared to larger hydro facilities. Life cycle costs are comparable to new coal or nuclear capacity, and hundreds of existing dams are potentially available for hydropower generation. The technology is also well-established, with components readily available throughout private industry.

DOE is focusing much of its attention on the near-term potential of small-scale hydroelectric power generation at existing dams. The major objective of the Department's programs is to re-establish a vigorous small hydro industry in the United States by identifying and minimizing the barriers to hydro development. One program to accomplish this objective is to provide loans for feasibility studies and licensing. DOE's near-term goal is to assist in providing 1,000 megawatts of capacity on-line or under construction by 1985 through loan programs and demonstrations.

Already, work has begun on 21 demonstration projects scheduled for completion by that year. Shown in Vol. III, *Project Summaries*, of this report (p. 80), these projects are intended to show the near-term viability of small-scale hydro with minimum Federal support (of a total capital construction cost of \$196 million, the owners invest \$169 million and DOE only \$27 million). Demonstration sites are located in Alaska, Arizona, California, Florida, Idaho, Illinois, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, South Carolina, Texas, Vermont, Virginia, Washington, and Wyoming. Two of the demonstration projects, one in California (Turlock Irrigation District) and one in New York (Goodyear Lake Power Station), went on-line near the end of 1980. When completed, the 21 projects will produce a total of more than 130 megawatts.

Although the technology of new dam construction with power facilities is mature, retrofit and ultra low-head technologies are not. These are now the two focal areas of efforts to develop cost-reduction technologies for hydro engineering projects. Retrofit technology is concerned primarily with siphon or dam penetration penstocks (using pumps as turbines) and with water and electrical control systems. Figure 5-7 shows a sawmill dam being upgraded to a 2,800 kilowatt powerplant. Ultra low-head technology development includes the design and testing of new turbines and the use of new materials (plastics or fiberglass) in existing design. Twelve ultra low-head design concepts are to be selected and funded in 1981, leading to the practical development of projects utilizing heads of 3 meters or less.

The Feasibility Study Loan Program, established under the Public Utility Regulatory Policies Act of 1978 (P.L. 95-617), was initiated during 1980. The regulations implementing the program were published in the *Federal Register* on January 17, 1980, and the effective date was

February 19, 1980. Within the first 9 months, over 200 loan applications were received and over 100 approved. The program provides loans for feasibility studies and licensing costs associated with hydro projects at dams with capacities between 100 and 30,000 kilowatts.

Other programs accomplishments during 1980 include convening five conferences dealing with institutional and economic impediments to and incentives for the development of hydro at the Federal and state levels; completing a national hydro site inventory, and a survey of existing dams in the Northwest; and completing a series of feasibility studies supported by DOE grants.

The Department expects to award approximately 450 loans in 1981. Experience to date indicates that about half of these loans could result in projects averaging approximately 3 megawatts. Thus, the loan-assisted projects have an estimated potential yield of 675 megawatts. Together with the demonstration projects, they should provide 815 megawatts towards the stated goal of 1,000 megawatts on-line or under construction by 1985.

DOE will also continue to coordinate and to support the President's Rural Energy Initiative (REI), a multi-agency effort to increase energy supplies in the Nation's rural areas. REI seeks to maximize the effectiveness of Federal programs in developing certain energy resources, including small-scale hydropower. Its target is to arrange financing for 100 hydropower sites by 1981, providing approximately 300 megawatts of additional capacity.

DOE's Regional Offices screen proposed projects that qualify for financial assistance under programs in the participating agencies, and refer them for consideration. DOE screened and referred approximately 100 candidate projects during 1980, and a similar number are expected to be processed during 1981.

During the coming year, the Department will address significant problems that may affect the development of small-scale hydro, by:

1. Supporting a National Conference of State Legislatures' program to assist states in creating a legislative framework to support hydro development.
2. Supporting state offices in establishing hydro programs and encouraging efforts to simplify state licensing procedures.
3. Making an aggressive effort to eliminate barriers to commercial development by conducting environmental studies and monitoring the implementation of regulations called for by the Public Utilities Regulatory Policies Act. These requirements pertain to utility grid interties and price of power paid to small-scale producers.
4. Providing loans for feasibility studies to help minimize the high risk of necessary initial evaluation of projects.

Figure 5-7—Sawmill dam being upgraded to a 2800-kilowatt powerplant

5. Providing general information for hydropower development, as well as field-based technical and institutional assistance, largely through the regional offices.
6. Continuing a program of examining technical constraints to reduce the costs of design, construction, operation, and maintenance.

Hydropower is already the most fully developed renewable energy resource. The challenges small hydro confronts today in its path toward commercialization will be faced by many emerging technologies in the future. Therefore, small hydro presents policymakers with a unique opportunity to understand and to develop the means for encouraging all renewable resources.

Small hydro is the cutting edge of vigorous efforts to reform Federal and state licensing and permitting processes. It will help establish new marketing arrangements between electric utilities and dispersed energy producers, and will create innovative financing techniques. It can also lead to harmonizing Federal-state relationships. In short,

the options and solutions selected today for small-scale hydropower development may well set patterns for other renewable resources through the rest of the 20th century.

Solar International Programs

The availability of substantial solar resources throughout most of the Earth's populated regions and the universal character of the energy dilemma has prompted many nations to embark on solar energy programs. Among the world's nations, the United States has launched the largest and most aggressive solar RD&D effort. It is an effort characterized by:

1. Multilateral and bilateral international agreements of mutual interests.
2. Assistance to U.S. industry to evaluate and develop international markets for U.S. products and services.
3. The promotion of global testing and commercialization of selected solar systems in cooperation with U.S. industry.

It is the Department's conviction that such activities promote the use of renewable resources, advance trade, and contribute to international stability.

A solar international strategy study was undertaken in late 1979 to develop a more cohesive international solar energy plan for an expanding number of international solar activities. The study considered solar activities aimed at advancement of U.S. solar technology development, stimulation of U.S. solar industries in marketing products and services abroad, and support of other U.S. agencies in implementing U.S. global energy policies to reduce world dependence on oil and firewood energy resources. And it has led to some changes in DOE's international solar program priorities.

In 1980, compared to 1979, there was a greater emphasis in international deployment and market development, with particular emphasis on developing countries. For example, a higher priority was placed on strengthening domestic U.S. industry through assistance in the assessment and development of foreign markets for U.S. equipment and services. Also, more attention was given to strengthening the technical and institutional capabilities of other countries and promoting earlier and expanded use of solar technologies abroad.

At the end of 1980, there were five U.S. solar agreements involved largely with the solar technology development initiative. These agreements are with the International Energy Agency (including seven multilateral implementing agreements in five areas of solar technology), Saudi Arabia (seven current projects in a 5-year, \$100 million jointly-funded program), Italy (three project annexes signed), Israel (three project annexes signed), and Spain (five project annexes underway).

The market development initiative in 1980 has been substantially expanded. Significant activities in 1980 included export-oriented workshops for U.S. industrial representatives, development of market profiles for about 35 countries, a greatly expanded data base of internationally oriented solar information on foreign companies and products, R&D projects, solar installations, solar product promotion exhibitions in other countries, and baseline studies of U.S. solar exports. A U.S. international photovoltaic commercialization plan for the Congress was completed during the year, technical visits were exchanged with several countries (e.g., Japan and France) and negotiations for further bilateral solar agreements were made with about 10 or more countries.

Joint research and development projects in 1980 under the U.S.-Spain solar agreement have yielded a number of design studies and the performance evaluation of two heliostat designs for central-receiver power systems, as well as analysis and planning reports on heating and cooling applications and impacts in Spain. With Italy, the United States completed an evaluation report on the poten-

tial role of central receiver solar thermal power systems in the Italian electric grid system. International efforts were also undertaken on the development of wind-turbine components and systems, wind resource modeling and measurement, large wind turbine design and testing, and new designs and tests for medium and large-scale wind turbines in Sweden, Denmark, the Netherlands, the Federal Republic of Germany, and the U.S.

Market development accomplishments include sponsorship of successful exhibitions of U.S. solar hardware in Milan, Italy; the completion of a comprehensive International Photovoltaics Commercialization Plan; the completion of 36 notebooks profiling the economic, political, and commercial situation for those countries with the greatest potential for solar development; and the completion of baseline study on the status of U.S. solar exports, products, and firms including markets of interest.

Within the seven IEA agreements in heating and cooling—solar power, biomass, wind, and ocean technology—the largest U.S. funding commitment is for a Small Solar Power System project involving nine countries in the design, construction, and testing of two parallel, but independent, 500 kilowatt electric solar thermal power plants. About 18 percent of the total project cost of approximately \$45 million is provided by the U.S. solar program. The operation of these plants will provide important information to the domestic solar thermal program. Anticipated benefits include information on the performance and delivered energy costs of two different design approaches to medium-sized solar thermal power systems, operation and maintenance information on the two systems under identical solar resource and environmental conditions, and new designs for collectors and heliostats.

DOE's international solar activities have expanded over the last 7 years at a relatively modest rate. Foreign interest in expanded international solar cooperation with the United States remains very high. At the same time, opportunities for U.S. benefits and contributions in joint projects is increasing as the level of foreign programs rises and as the needs for global solar energy alternatives becomes more desperate. Thus, the opportunities and benefits of international solar activities appear to be increasing.

Geothermal Resources

Introduction

Geothermal energy is one of the cleanest, safest, and cheapest energy sources available today around the world. Consisting of concentrations of the Earth's thermal energy stored in subsurface rocks and fluids at accessible depths, geothermal resources can be used for electric power production, residential and commercial space heating and cooling, industrial process heat, and agriculture. Hydro-

thermal, geopressed, and hot dry rock are the three principal types of geothermal resources (in order of technological readiness).

Hydrothermal resources include hot water and steam trapped in relatively near-surface fractured and porous rock. Worldwide installed geothermal electric capacity is 2,100 megawatts electric, with expansion planned through 1984 of about 3,800 megawatts electric among 14 countries. Nine countries are making significant use of geothermal heat for non-electric applications amounting to some 7,200 megawatts thermal.

In the United States, electricity is generated at The Geysers steam field in California. The economic production of power from hot water reservoirs is expected in several western states in the near future. Hydrothermal direct heat is being used in a number of western states and could now be used at many more sites, including some in the East. Geopressed resources are hot water aquifers containing dissolved methane trapped under high pressure in deep sedimentary formations. Commercial production of energy (primarily methane) from these large resources may begin in the late 1980's along the U.S. Gulf of Mexico coast. Hot dry rock resources are geologic formations at accessible depths that have abnormally high heat content but contain little or no water. Usable energy is extracted by circulating a heat transfer fluid, such as water, through deep wells connected by man-made fractures in the rocks. Commercial production of energy from these very large resources is expected to occur in the early 1990's.

Estimates of the thermal energy that could be recovered from the three resource types are presented in Table 5-2. These estimates depend on a number of factors, including the available supply of geothermal energy, the economics of energy extraction, the economics of energy conversion, and estimates of future demand for electricity

Table 5-2. — Energy recoverable from U.S. geothermal resources

	<i>Quads</i>	<i>Oil Equivalent in billions of barrels</i>
Hydrothermal ¹		
150°C	85-140	15-25
90-150°C	200-300	40-60
Geopressed ¹		
Thermal	30-300	5-60
Methane	75-800	15-150
Hot dry rock	200-2000	40-400

¹From U.S. Geological Survey *Circular 790*—Estimate of the amount of thermal energy that might feasibly and economically be extracted from the Earth at some future time.

and heat. The energy supply estimates are based on application of economic studies to the resource estimates given in the U.S. Geological Survey *Circular 790*, which was published in early 1979. It provides estimates of the energy potential at known specific sites as well as of inferred resources yet to be located.

Figure 5-8 shows those areas of the U.S. that have been identified as having known or potential hydrothermal resources; 37 states are included. The western part of the country possesses potential for hydropower development, particularly for electrical power generation and direct heat applications that require relatively high temperatures. The Atlantic coastal area and southeastern states contain a number of prospective targets for development as low- to moderate-temperature heat sources. Geopressed resources are located primarily along the Texas and Louisiana Gulf Coast, but their existence has also been indicated in sedimentary basins elsewhere. Hot dry rock resources are generally widespread in the western states and may also exist in the East.

Federal Geothermal Energy Program

The overall mission of the Department's program is to foster the rapid characterization, development, and use of geothermal energy resources in the United States. In the near-term, geothermal energy from hydrothermal resources can displace oil and natural gas as an economical and environmentally attractive source of energy. In the mid- and long-terms, geothermal resources are expected to supply natural gas from geopressed resources and very large quantities of useful heat from hot dry rock resources. The program's specific goals are summarized in Table 5-3.

Seven major barriers currently impede the commercial development of geothermal energy and the attainment of these goals:

1. The initial risk associated with the costly drilling needed to confirm new geothermal reservoirs of all types prevents many potential users from starting projects.
2. The vast majority of higher temperature reservoirs suitable for electric power production are only marginally economic with present technology.
3. The overall rate of leasing of Federal lands appears to be too slow to sustain rapid development of hydrothermal resources in the 1990-2000 period.
4. Present state laws need further development to promote a clear legal climate for industrial geothermal activities.
5. An industrial infrastructure to support direct heat applications is lacking.
6. Potential users and developers generally lack knowledge about geothermal energy.

Figure 5-8—Known and potential hydrothermal resources. The KGRA refers to known geothermal resources area

*Table 5-3. —Interagency geothermal coordinating council
national geothermal utilization goals (by application)*

<i>Electric power capacity (MWe)</i>	<i>1980</i>	<i>1985</i>	<i>1990</i>	<i>1995</i>	<i>2000</i>	<i>2020</i>
Hydrothermal	792	3,000	7,000	14,000	25,000	50,000
Geopressured (thermal)	0	10	70	500	2,000	5,000
Hot dry rock ¹	0	10	35	135	700	6,800
Total MWe (rounded)		3,000	7,000	14,000	28,000	62,000
Fossil fuel equivalent	0.05	0.24	0.6	1.2	2.2	4.9
<i>Direct heat applications</i>						
Hydrothermal	0.01	0.1	0.2	0.4	0.1	6.0
Hot dry rock ¹	0.00	0.001	0.001	0.004	0.007	0.6
<i>Geopressured methane</i>	<u>0.00</u>	<u>0.02</u>	<u>0.1</u>	<u>0.7</u>	<u>3.0</u>	<u>7.0</u>
Total quads (rounded)	0.06	0.40	0.9	2.3	6.2	18.6

¹These are not set as goals; only estimates of production can be given at this time.

7. The technology and economics have not been proven for geopressured and hot dry rock resources.

Table 5-4. The aggregate of these strategies lead to a carefully balanced mix of research and development projects and financial incentives (including the Geothermal Loan Guaranty Program); research and development is directed as cost reduction and the incentives at assistance in sharing front-end risks and exploiting new reservoirs. In turn, the selection of appropriate Federal activities is dominated by the consideration that five distinct and advantageous modes of using geothermal resources exist. The nature of the Department's program, plans and accomplishments are best discussed in terms of these modes of resource utilization.

High-Temperature Hydrothermal Resources for Electric Power Generation: The technology for exploitation is available, is cost-competitive, and is used today on a limited scale. The program emphasizes the acceleration of industry's exploitation of the resources base through tax incentives, loan guarantees, applied research and development (to reduce system costs and to resolve critical technical problems), assistance in confirmation of new reservoirs, and the demonstration of full-scale (50 megawatt electric) production from liquid-dominated reservoirs.

To encourage and assist the private sector in accelerating the developing and utilization of hydrothermal resources, DOE supports the Geothermal Loan Guaranty Program. Its objective is to minimize the lender's risk so that credit can be made available for construction and operation of geothermal plants, for a variety of projects, and for field exploration.

During 1980, loan guarantees totaling \$93.1 million were authorized for field development at Brawley, Cali-

fornia, and a power plant at The Geysers, California. Four applications for loan guarantees totaling about \$110 million were being processed as the year drew to a close. The aim is to encourage normal borrower-lender relationships and flow of credit to the geothermal industry, to enhance competition, to encourage new entrants into the geothermal market, and to commercialize geothermal resources.

Two new geothermal fields entered operation in the Imperial Valley of California under private funding. The world's first commercial geothermal binary cycle plant (10 megawatts electric) was installed at East Mesa, California, and shakedown tests got under way for a flash-steam plant of the same capacity at Brawley, California.

The Geothermal Loop Experimental Facility at Niland, California, was decommissioned during the year, following completion of the evaluation of the feasibility of flash-steam and steam-binary systems for production of electric power from high-temperature, high-salinity resources. Success in demonstrating the equipment and in developing techniques for handling the Niland geothermal brines led Magma Power and San Diego Gas and Electric Company to agree to build a 50 megawatts electric flash-steam power plant at this location. It is expected to be operational by early calendar year 1983.

Construction of a 3 megawatts electric wellhead generator system began at the Puna site in Hawaii; operation by a local utility is scheduled for May 1981. The project is expected to lead to commercial applications of wellhead generators in remote areas of the western continental United States, Hawaii, and other parts of the world.

During the year, an environmental impact statement and record of decision were completed for the 50 megawatts electric, flash-steam demonstration plant at the Valles Caldera site in New Mexico. This led to the beginning of site preparation and well drilling. The plant is

Table 5-4. — Principal program objectives and corresponding strategies

<i>Objective</i>	<i>Strategy</i>
To reduce uncertainties associated with capacity estimates of identified resources.	Intensify regional resource assessment to meet near- and mid-term power-on-line goals.
To identify and quantify the approximately 80 percent of the estimated U.S. geothermal resource not yet located.	
To assist with technology improvements that are likely to reduce geothermal energy costs, to expand the economically competitive resource base, and to lead to more rapid commercialization.	Continue an aggressive research and development effort.
To accelerate the implementation of new projects.	Propose ways in which Federal leasing and permitting processes can be simplified.
To encourage state participation in geothermal development.	Assist states in site-specific planning and outreach activities.
To encourage potential nonelectric users to initiate projects.	Develop means to reduce front-end risks and provide general technical assistance.
To assess the environmental impacts of geothermal development that could delay development.	Establish appropriate environmental regulations, continue monitoring of environmental effects at each resource area, and develop control technology and procedures for mitigating problems such as hydrogen sulfide emissions, subsidence, noise, and disposal of brines.
To encourage capital investment through risk sharing.	Provide Federal loan guarantees.

expected to be operational in 1982, and will provide technical and economic operating data, hands-on experience for industry, and demonstration of new technology, equipment, and systems. It will also serve as a "pathfinder" for the regulatory process and other legal and institutional aspects of geothermal development.

Moderate-Temperature Hydrothermal Resources for Electric Power Production: A much larger resource base than high-temperature hydrothermal is involved here, requiring the development and demonstration of binary cycle electric power generating systems, where the turbine generator is driven by an organic working fluid. The reduction of development costs, the confirmation of reser-

voirs to support post-1985 electric production goals, and pilot (5 megawatts electric) and full-scale (50 megawatts electric) demonstration plants designed to prove the new technology should combine to result in a mature and economically competitive technology by 1985.

DOE is developing drilling, energy conversion, and well stimulation technology to reduce electric generating costs. Particular emphasis is given to moderate-temperature resources which, though more prevalent than high-temperature resources, are inherently more expensive to exploit. It is felt that improved drilling technology can reduce the cost of geothermal wells 25 percent by 1983 and 50 percent by 1986.

Commercialization efforts are presently underway for the successfully tested downhole replaceable chain drill bit and candidate technology for advanced drilling systems is being evaluated. Also, conversion technology development is being undertaken to improve performance and to reduce costs of heat exchangers, which now account for 50 to 70 percent of binary power plant costs. A 500 kilowatt, skid-mounted isobutane binary power system employing direct contact heat exchangers is undergoing field tests at East Mesa, California.

Stimulation technology is being employed to increase fluid productivity of wells, thereby reducing the number of wells required to exploit a reservoir. Methods for stimulating geothermal wells include hydraulic fracturing, explosive fracturing, and chemical treatment. The stimulation of two wells in the Raft River Valley of Idaho by hydraulic fracturing was successfully completed during the year, with production increasing threefold at one well. Newly developed, high-temperature explosives were (and are being) used in explosive fracturing tests of a well in The Geysers geothermal field.

Construction is continuing on a 5 megawatts electric pilot plant using a binary Rankine Power cycle at Raft River, Idaho. The plant will use energy from a moderate-temperature (150°) hydrothermal resource to generate electricity for a utility power grid. Scheduled to begin operations in early 1981, the project should supply valuable technical and economic data on geothermal reservoir performance.

Hydrothermal Resources (All Temperatures) for Direct Heat Applications: The technology for direct use of geothermal energy for space heating and process heat is well developed and economical, but confirmation of a larger number of reservoirs located near use sites is required. To stimulate independent industrial activity, which is just beginning in relatively small and fragmented markets, the Department of Energy supports a number of activities. These include demonstration and reservoir confirmation projects, financial incentives and risk sharing, technology transfer, reduction in legal impediments, and R&D aimed at reducing cost and increasing reliability.

Twenty cost-shared, direct heat demonstration projects are now under way. The majority are for space and district heating applications, while three are directed at agriculture and three involve industrial processing.

The Department's current direct heat applications field experiments should prove the viability of direct geothermal heat use in a number of geographical locations and also yield definitive technical and economic data to encourage the spread of industrial involvement and the building of a direct-use infrastructure. In support of this effort, eight new cost-shared engineering and economic studies of direct-use applications were initiated in 1980. Four involve direct-heat use for ethanol plants. It is also encouraging to note that the first geothermal ethanol plant is in production at La Grande, Oregon. It was established under private funding.

Analyses of potential direct-use applications were performed during the year, to define the market according to size, particular end-users, location with respect to resource, density of users within geographic areas, and engineering feasibility. An analysis of energy supply and demand on a site-specific basis was initiated in an attempt to predict the degree of market potential and to identify actions and events that would increase market penetration.

A limited exploratory drilling program was completed in several regions where suspected but unconfirmed low-to-moderate temperature resources exist. Examples include the Snake River Plain, the Atlantic Coastal Plain, and the Mount Hood region. A solicitation for proposals was issued during the year as part of a user-coupled reservoir confirmation program. Competitively selected teams composed of a developer and a user will share the cost of surface exploration and drilling to locate and confirm a reservoir that could be commercially developed for direct heat applications.

The drilling of the first of two moderate-temperature wells for direct heat use was initiated in the Mount Hood area. Interest was expressed in the use of hydrothermal energy for district heating in the city of Portland and for space heating of facilities on or near Mount Hood. Drilling activities were also initiated in the East Coast's Delmarva Peninsula to confirm a resource for a major industrial user of process heat.

Geopressured Resources

Geopressured resources contain a thermal energy component for electricity production and for direct-heat applications. However, most interest in this resource has been concentrated on its methane component. The Gulf Coast oil and gas industry is expected to develop this resource if it can be demonstrated that production is economical.

In prior years, some promising reservoirs were identified where production tests can be conducted in environmentally acceptable ways. Thousands of wells have already penetrated geopressured aquifers in search of oil and gas in other horizons in the Gulf Coast sediments, so it is a matter of defining and delineating by logs from these wells the magnitude of the resource. Coupled with seismic surveys and core analyses, these studies successfully led to the location of 70 areas with high potential for geopressured production.

Major 1980 accomplishments include final preparation for long-term testing of the geopressured well in Brazoria County, Texas; starting the recompletion of an existing gas well in Louisiana for geopressured aquifer testing and negotiations for four additional wells-of-opportunity in the Gulf Coast; the start of two new geopressured drilling projects for designed production wells in Louisiana; and the issuance of a solicitation for proposals for the drilling of four additional geopressured wells in Louisiana and Texas.

Hot Dry Rock Resources

The technology for exploiting the enormous heat content of dry geothermal resources was proven at one site to be technically feasible on a pilot scale. Program emphasis, therefore, is on technology improvements, reservoir engineering, and economics through continued R&D at this site, and on extending experimentation to a second site with different geological characteristics.

Major accomplishments include the generation of 60 kilowatts of electricity on a continuous basis at the Fenton Hill, New Mexico, research installation to demonstrate the technical feasibility of electric power production from hot dry rock resources; the completion of drilling of the first well for a large (20-50 megawatt thermal) hot dry rock thermal loop to be established at the Fenton Hill site for test of hot dry rock technology; and the execution (under the auspices of the International Energy Agency) of a cost-shared agreement with the Federal Republic of Germany for participation in the Fenton Hill hot dry rock project.

Outlook

Private industry plays the leading role in planning and constructing geothermal energy systems. The Department of Energy's role is to help the geothermal industry to act more rapidly and also to encourage additional resource developers, utilities, financial institutions, and consumers to enter the geothermal marketplace. DOE plans to maintain a close working relationship with industry to enhance the rapid development of geothermal resources.

Hydrothermal energy has great potential in the near-term. The pace of development is rapidly accelerating.

Figure 5-9—Artist's conception of hot dry rock extraction process

Barring unforeseen environmental problems, it seems likely that more plants will be built and more resources developed by the middle of this decade than previously estimated.

For example, utility companies have publicly announced their intention to build hydrothermal electric generating plants using hot water resources to produce generating capacity totalling more than 1,000 megawatts electric. This, along with the announced expansion of dry steam generating capacity at The Geysers to 1,900 megawatts electric, would result in an installed capacity of about 3,000 megawatts electric by 1985.

The geopressured resource is large, but little is known about the recoverability of its methane, thermal, and hydraulic energy. Consequently, geopressured energy use is best viewed as a mid-term probability. Tests of the first design production well in Brazoria, Louisiana, is scheduled to be completed in 1982 and tests of additional design wells are to be made through 1986. If they show technical and economic feasibility, commercial development of geopressured resources could begin in 1987.

Extensive use of hot dry rock resources is a long-term possibility. A 5-megawatt thermal loop has been operated at the Fenton Hill site in New Mexico. In 1981, Phase II drilling at Fenton Hill is scheduled to be completed and steps are to be taken to establish a 20 to 50 megawatts thermal loop. Future development and evaluation of the hot dry rock reservoir at Fenton Hill will continue to be conducted in concert with the international agreement between the United States and the Federal Republic of Germany. The industrial infrastructure associated with hydrothermal resource development is expected to be applicable to the development of hot dry rock, once the technology and economics become favorable.

Magnetic Fusion

Fusion is the third of the essentially inexhaustible energy sources described in this chapter. Its fuel is cheap and virtually unlimited in supply and its byproducts pose relatively few environmental problems.

Two types of fusion are being investigated by the Department of Energy, magnetic and inertial confinement. The former is covered here and the latter—because of its potential for military application—is reserved for Chapter 13 on Defense Programs.

The goals of DOE's magnetic fusion program are to develop the highest potential of this energy source for the generation of electricity and to evaluate other applications of the fusion process. The latter include the production of fissile fuel to extent uranium and thorium resources and the production of synthetic fuels or chemical feedstocks.

To produce commercial fusion energy here on Earth, the fundamental energy processes of the universe must be

harnessed. The Sun is a giant fusion reactor whose energy is produced by gravity and the fusion process. Fusion occurs in the Sun where gravitational forces compress and heat its substances to about 15 million degrees centigrade. The pressure and temperature working together cause atoms to break apart and allow the nuclei, driving into each other, to fuse.

In a fusion reaction, light nuclei strike each other with such speed that the nuclei combine, or fuse, to form a larger atom and, in the process, release energy. Fusion reactions are difficult to produce because nuclei are positively charged and thus repel each other. A temperature of 100 million degrees centigrade is needed to attain the speed for fusion to occur.

The temperature of the fusion fuel, or plasma, must be maintained for a fusion reaction to occur. No existing material vessel can hold a substance at such a high temperature. If such a container did exist, the plasma would have to be kept away from the walls. If it touched the walls, the plasma would transfer some of its heat to them, lowering the temperature below that required for fusion to occur. The basic challenge of the fusion program has been to contain or confine the plasma long enough for fusion to occur.

The efforts of the fusion program to contain the plasma are focused on two magnetic confinement systems. The term magnetic fusion stems from the fact that plasma consists of charged particles that can be restrained by magnetic fields. Two basic magnetic field configurations exist: closed and open. In a closed system, the magnetic lines of force circle in on themselves in the shape of a doughnut or toroid. The tokamak, one such toroidal device, is the most advanced and best understood magnetic fusion device.

In the open or linear confinement system, magnets are placed near the ends to squeeze the magnetic lines of force and thus prevent the plasma from leaking out. These devices are referred to as mirror devices because some of the particles are reflected rather than escaping out the ends.

Research on both the open and closed systems is aimed at making the plasma hot and dense enough, and at confining it long enough, for many fusion reactions to occur at once. Enough simultaneous fusion reactions are needed so that more energy is produced than it takes to heat and confine the plasma. The production of as much energy by the device as it takes to operate it is termed *energy breakeven*. Its attainment is considered proof of scientific feasibility and is the touchstone of practicality for fusion as an energy source.

Current program efforts are carried out in four inter-related functional areas, which together form the basis for a unified R&D effort to develop magnetic fusion technology. Within the confinement systems activity, ex

Experimental programs are conducted to demonstrate and refine methods of heating and containing high-temperature plasmas. Development and technology seeks to develop the capability to design, construct, and operate increasingly larger and more complex fusion experiments and facilities. Applied experimental and theoretical studies of the fusion plasma phenomena are pursued within the applied plasma physics effort. The aim is to develop the knowledge required to predict plasma behavior in confinement systems and future fusion power systems, and to perform critical experimental tests and assessments of alternate fusion concepts. Planning and projects is responsible for the conduct of R&D in the support and management of construction activities on the next generation of fusion devices.

In support of its goal for developing magnetic fusion energy, DOE is constructing several facilities to house future fusion experiments. One such facility is the Tokamak Fusion Test Reactor (TFTR) aimed specifically at demonstrating scientific feasibility. It is being built at the Princeton Plasma Physics Laboratory in Princeton, New Jersey, and is scheduled for completion in December 1982.

Another project, the Mirror Fusion Test Facility is being constructed at the Lawrence Livermore Laboratory in Livermore, California. When completed in 1985, it will be the largest experimental facility in the world capable of studying the tandem mirror concept.

The Elmo Bumpy Torus Proof-of-Principle Experiment is being constructed in Oak Ridge, Tennessee. In addition to advancing the bumpy torus concept, which combines aspects of open and closed confinement systems, it is expected that the fusion program, in general, will benefit from advances in superconducting magnet and gyrotron microwave heating technology. This project is scheduled for completion in 1986.

The Fusion Material Irradiation Test Facility will allow for the testing of various materials for their ability to withstand the severe radiation environment of a fusion reactor. It is being built at the Hanford Engineering Development Laboratory in Richland, Washington, and is scheduled for completion in April, 1985. More detailed information on these projects is on pages 72-77 of *Project Summaries*, which is Volume III of the *Secretary's Annual Report to Congress*.

Figure 5-10 illustrates how the four functional areas and the above facilities interrelate and contribute to achieving the ultimate goal of commercialization.

In achieving the goal of usable fusion energy, three general phases of development are encountered: achievement of scientific feasibility, technological and engineering feasibility, and commercial (economic) feasibility.

With the first major goal, achieving scientific feasibility, likely to be demonstrated in the mid-1980's, the focus of

the program is now beginning to shift into the engineering development phase. The decision to initiate this shift is consistent with findings of a review of the fusion program carried out in 1980 by the Department's Energy Research Advisory Board. The Board recommended that the "magnetic fusion program can, and should, embark on the next logical phase toward its goal of achieving economic feasibility by the mid-1980's."

The central role in the engineering development phase will be played by a new Center for Fusion Engineering where a tokamak-based fusion engineering device will be designed and constructed. It will provide a focus for developing and testing reactor-relevant technologies and components and for exploring and resolving problems of operator and public safety. The equally important research in alternate confinement systems and advanced tokamak physics will continue, as will theoretical and experimental plasma physics research essential to support advances in fusion technology.

The successful operation of the fusion engineering device, by 1990 in parallel with advanced physics and alternate concepts research, should provide sufficient information to assess the engineering practicality of fusion energy; that is, when and under what circumstances an economically practical reactor can be built. Following the achievement of this goal, a reactor could probably be designed and constructed to operate soon after the turn of the century.

Progress has been very encouraging in both tokamak and mirror confinement systems, and in technology development. The parameter values necessary for ignited plasma, one in which fusion reactions proceed without external energy being supplied, have all been individually reached, although not all together in one machine. These capabilities are being combined in the Tokamak Fusion Test Reactor, which is expected to demonstrate scientific feasibility by the mid-1980's.

During 1980, important accomplishments were made in the development of tokamak systems:

1. Significant progress was made toward completion of major buildings of the Tokamak Fusion Test Reactor at the Princeton site. A prototype neutral beam injector at the Lawrence Berkeley Laboratory operated at full power and pulse length. This is a major milestone in heating TFTR plasmas.
2. The Princeton Large Torus, a tokamak machine, extended its earlier results to achieve ion heating in excess of 80 million degrees, very close to ignition temperature.
3. The efficiency of the use of magnetic fields is important in making fusion reactors small and economical. In 1980, in the ISX-B experiment at Oak Ridge National Laboratory, the efficiency was raised from about 3 percent to about 4 percent,

Figure 5-13—Project flow to commercialization

close to the 5-10 percent range required for economical reactor operations. Advanced limiters were demonstrated on an ISX-B that can operate at high temperatures for long periods without introducing high atomic weight nuclear impurities.

Progress was also recorded with open mirror systems:

1. A new thermal barrier concept offers significant theoretical improvements for reducing end losses. The concept essentially involves using two plasmas—the plasma in the center and a plasma in the “plug” at the ends. The less dense plasma at the ends is heated to higher temperatures than the center plasma. This creates a difference in the electrical fields of the two plasmas and, thus, particles are reflected back into the center. Designs for two construction projects which incorporate this concept, the Mirror Experiment-Upgrade and the Mirror Fusion Test Facility-B, were completed and were reviewed and approved for construction by DOE.
2. The Tandem Mirror Experiment at Lawrence Livermore National Laboratory operated successfully during 1980, providing evidence for electrostatic reduction of end losses from a Tandem Mirror Configuration without using the thermal barrier concept.

3. Elmo Bumpy Torus 1/5 data were greatly extended, revealing excellent agreement with the neoclassical transport theory (a theory for predicting the value of the confinement parameter). A reference design for the Elmo Bumpy Torus Proof-of-Principle device was prepared and an industrial contractor selected.

Two principal activities were carried out in the field of technology development.

The first involves the Fusion Material Irradiation Test Facility, where significant progress was recorded in accelerator development, permitting a full accelerator design to proceed. The facility is expected to play a crucial role in the fusion program since it will provide a basis for materials selection and testing. (The successful design and operation of commercial fusion powerplants will require materials and property data at operating conditions beyond those currently experienced.)

The second accomplishment in the technology development area is the successful development of a 200 kilowatt, 28 gigahertz gyrotron with an efficiency of about 50 percent. This development enhances the prospects for using radio frequency for various plasma heating applications.

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Chapter 6

Electric Energy Systems and Energy Storage

Introduction

The U.S. electric energy network is a vast, complex, and multifaceted system comprising many elements that provide connections between sources and uses of electric energy. These elements, and their interrelationships, must be completely understood if present and future electric energy requirements are to be dealt with effectively. The electric energy system will become even more complex as the electric energy generation mix gradually changes from centralized sources (fossil, nuclear, high-head hydropower) to dispersed and often intermittent sources (fuel cells, photovoltaics, low-head hydropower, wind).

When used as the link between energy source and end use, energy storage can correct the timing mismatch between supply and demand in the electric energy industry. Energy storage systems are designed to increase the substitution of coal, nuclear, and solar energy for oil and natural gas, and to provide continuous power from intermittent energy sources. Energy storage contributes to oil and natural gas reduction in the building, transportation, and industrial sectors, and helps solve economic and operating problems facing electric utilities in satisfying peak demands. Energy storage systems have the potential of saving the United States the equivalent of up to 1.3 billion barrels of oil annually by the year 2000.

Electric Energy Systems

The Nation's electric energy system is remarkably efficient in meeting the demands placed upon it—so efficient, in fact, that its performance is often taken for granted. However, the capability that gave rise to this performance resulted more from evolutionary circumstances than from a national electric energy system planning effort. It would be both risky and unwise to trust evolution alone to develop an electric energy system for the future that will be able to meet growing, changing, and complex requirements.

The overall goal of the Electric Energy Systems (EES) program is to help ensure that the Nation will have a strategy for developing and improving systems for the generation, transmission, and distribution of electricity that are more efficient and reliable, have greater capacity, and have less impact on the environment than those of today.

The Electric Energy Systems program strategy calls for: (1) assessing the needs of the electric energy system in light of national energy policy; (2) examining research and development programs being performed by utilities and private industry to meet these needs, and (3) providing support for the required system technologies if it is not provided elsewhere.

This translates into a dual function that requires the Department to act as an agent for the electric energy con-

sumer and as an architect for the electric system. EES efforts have thus concentrated on the system approach, since overall economy, efficiency, and reliability can be achieved only by integrating the generation, transmission, distribution, and utilization of electric energy into one comprehensive system.

The EES program is divided into power delivery, system architecture and integration, and generation and storage applications. Power delivery involves the development of high voltage alternating current (HVAC) systems, high voltage direct current (HVDC) systems, underground cables, and studies of electric field effects. System architecture and integration encompasses systems control and development, load management, and integration of new technologies. Generation and storage applications activities include conducting feasibility tests on the systems and equipment of selected new technologies (activities in this area are discussed under the Energy Storage for Solar and Conventional Utility Applications subsection of this chapter.)

Power Delivery

The power delivery effort focuses on research and development of key electric energy transmission and distribution equipment for future systems. In the principal equipment areas (cables, compact stations, overhead transmission, and improved system efficiency), the objective is to develop commercial systems that increase power transfer capability while lessening adverse environmental impact.

Increased power density, coupled with the need for transmitting large blocks of power from central generating plants that are remote from populated areas and for providing backup to regionally concentrated intermittent sources, requires high capacity electric bulk power delivery facilities.

During 1980, major elements of the future 1200-kilovolt bulk power transmission system were completed and underwent testing. These elements include current and voltage sensors, lightning arrester, and gas-insulated cable and termination. Other equipment in the prototype development phase includes the 1200-kilovolt circuit breaker and gas-insulated transformer. All represent major technical breakthroughs in the use of materials, miniaturization, and innovative electrical and mechanical designs. Some elements are being tested at the Electric Power Research Institute's Waltz Mill test facility in Pennsylvania, and others will utilize Bonneville Power Administration facilities. Spinoffs from the new designs are already appearing in lower-voltage commercial products.

The alternating current superconducting cable test at Brookhaven National Laboratory successfully completed its first cool-down for the 100-meter cryostat cable. The first long section (100 meters) of this cable is being assembled, and long-term testing will follow. Superconductivity is expected to play a major role in future elec-

trical systems because it minimizes electrical resistance and thus significantly affects the design of equipment. In addition, it combines higher efficiency with smaller size. Figure 6-1 illustrates a superconducting cable undergoing wrapping at Brookhaven National Laboratory.

HVDC networks, used either as an overlay to existing alternating current systems or in new arrangements to link load centers, offer considerable promise for economically transmitting bulk power, enhancing systems stability, reducing environmental effects, and increasing power delivery reliability. The least efficient part of the HVDC systems has been the alternating-current/direct-current converter. A newly developed nondestructive analyzer device was placed in commercial use to determine the quality of "growth" crystals (vital to the converter). This device permits high performance crystals to be selected, thereby increasing the conversion efficiency of this key HVDC equipment.

Institutional and environmental issues have delayed completion of almost all transmission line construction. One such issue is the unknown effect of high voltage electrical fields on plants, animals, and humans (see Figure 6-2). EES completed during the year the first phase of research into the effects of electric fields on living organisms. This was done by performing carefully developed tests on fruit flies. Work continued on the effects of these high voltage fields on small animals and will proceed in 1981 to large primates and to the scaling factors required to relate these data to humans.

System Architecture and Integration

The objective of the system architecture and integration program is to ensure that all new sources (including storage) are integrated into the electric grid system. This is accomplished by developing needed system methodologies, conducting field tests and technology demonstrations, developing data for power system planning, transferring system information on new source technologies to public and private utilities, and encouraging the early industrialization and penetration of these technologies into the electric energy system.

The near-term use of heat-and-cool storage¹ (especially heat) could facilitate the use of solar energy in the residential and commercial marketplace. Installation of heat-and-cool storage load management tests were completed in selected regions during 1980 to determine the system effects of various storage scenarios.

An integrated test was initiated during the year on load management and distribution automation and control, with capability to place selected dispersed storage and

¹Work designed to determine the effect of customer-owned storage for either heating or cooling on the electric system.

Figure 6-1—Superconducting Power Cable Undergoing Wrapping. Layers of polymer plastic tape and niobiumtin are intricately and precisely wrapped around a hollow copper cable core at Brookhaven National Laboratory.

generation sources. A contract was signed to utilize the Athens, Tennessee, municipal system as the test site, which is within the territory of the Tennessee Valley Authority.

Software was installed and tested on the Wisconsin Electric Power utility system during the year. This should provide advanced automatic generator control, increasing the efficiency of powerplants and reducing maintenance costs.

As electric energy systems become more complex, it becomes difficult to determine when the system is gradually moving away from a state of normal operation into an emergency condition. Breakthroughs were made during the year using real-time, locally derived data to warn system operators of pending changes in system stability.

Energy Storage

The Energy Storage program is helping the private sector develop reliable, cost-effective, and environmentally acceptable systems that facilitate increased substitution

of coal, nuclear, and solar energy for oil and natural gas; allow solar and other intermittent energy systems to provide continuous service; conserve energy by storing industrial and utility waste heat for later use and by improving the efficiency of electrochemical processes; and improve electric utility efficiency by shifting electric generation away from peak load times.

Six major energy storage technologies are under development: electrochemical (batteries), mechanical, underground, thermal, chemical, and magnetic. These technologies will be used in transportation, building heating and cooling, both solar and conventional utilities, and industrial and multipurpose applications.

Energy Storage for Transportation

Storage for transportation is the link between stationary nonoil sources and the mobile energy source needed for vehicles. Working with the private sector, DOE is developing advanced batteries to power electric vehicles and flywheels to store momentum energy from

Figure 6-2—High-Voltage Electrical Transmission Lines. The feasibility of transmitting electricity at very high direct current voltages is being explored at this facility in Lenox, Massachusetts. The main emphasis of this research program is the identification of the environmental effects of high-voltage electrical fields.

braking to improve electric/hybrid vehicle performance. The aim is to evolve batteries that give electric cars ranges, acceleration, and cruising speeds similar to gasoline-powered cars. Today's batteries permit electric vehicles to reach a range of 30 to 45 miles and an acceleration of 0 to 30 miles per hour in about 15 seconds. Batteries under development for the near term (early 1980's) will provide a range up to 100 miles in stop-and-go driving, and approximately one-third better acceleration. Near-term batteries include improved lead-acid, nickel/zinc, nickel/iron, and zinc/chlorine. All of these are now being field-tested in vehicles.

Current emphasis in advanced batteries for transportation is on lithium/metal sulfide and aluminum/air battery development. By the late 1980's, lithium/metal sulfide batteries are expected to provide vehicles with a range up

to 150 miles and an acceleration of 0 to 30 miles per hour in less than 7.5 seconds. During 1980, laboratory testing of multicell lithium/metal sulfide batteries demonstrated more than 300 charge-discharge cycles, and tests are continuing. In the 1990's, aluminum/air batteries are expected to provide vehicles with a range up to 250 miles and an acceleration from 0 to 30 miles per hour in 6 seconds, a performance competitive with gasoline-powered vehicles. During 1980, successful full-size aluminum/air cells were demonstrated in the laboratory. Development is continuing on several other high-energy density batteries.

Also during the year, the Department tested full-sized, 20- to 30-kilowatt hour, near-term batteries in vehicles. The laboratory testing capability for electric vehicle batteries includes eight battery test stations that can handle up to 30

modules as well as environmental and vibration testing.

Flywheels, when used for regenerative braking, convert the braking momentum of a vehicle back into usable energy and store that energy for later use in vehicle acceleration. This method for storing and recovering braking energy can increase the range of electric vehicles by as much as 25 percent in urban driving involving frequent starts and stops; it can also increase battery life and improve acceleration. Regenerative braking also improves the fuel economy of gasoline-powered vehicles. DOE is continuing its efforts to improve flywheel technology, through development and characterization of materials and motors for flywheels and through other research.

Energy Storage for Building Heating and Cooling

Several thermal energy storage concepts being developed for building heating and cooling can save money for both the customer and the utility. The customer would pay less for the energy used for heating, and the utility would be able to eliminate the extra operating costs of inefficient petroleum-fired, peak-load generating equipment.

Concepts for improved performance being developed by DOE for application in solar heating and cooling systems include phase-change materials and chemical heat pumps. When certain materials undergo a phase change (e.g., liquid to gas), they give up large amounts of heat relative to the amount of energy required to cause the material to change. The three general types of phase-change materials used for storing energy are inorganic salts, complex organic compounds, and solutions of salts and acids. Phase-change materials can be part of a separate storage module or integrated directly into the structure, providing "built-in" climate control. Modular phase-change storage system concepts and materials are being developed for active solar heating and cooling. Building materials with phase-change storage capability are intended primarily for passive solar heating and cooling systems. The Department is conducting cost-effectiveness and marketability studies of the "built-in" phase-change technique and investigating long-term material stability and life under multiple cycles through the phase-change temperature range.

In another concept, heat may be stored by concentrating a sulfuric acid-water solution. Subsequent heat release is accomplished by returning water to the solution. In solar heating and cooling systems, such chemical heat pumps perform the functions of thermally driven heat pumps, chillers, and storage systems. Chemical heat pumps make possible lower overall cost and greater efficiency than solar heating, cooling, and storage systems. Chemical heat pumps have been successfully operated in a bench-scale model for a building heating application. DOE's Brookhaven National Laboratory is funding the construction of a larger unit for demonstration testing in late 1981.

Industrial or utility waste heat can be stored in aquifers for subsequent use in district heating systems, thus increasing the capacity of the system. Heat that would otherwise be discarded is stored in the aquifer during the summer and used to heat buildings during the winter as shown in Figure 6-3. Similarly, winter air can be used to chill water that is returned to the aquifer and withdrawn during the summer for use in cooling systems. DOE-sponsored field tests of aquifer storage at two southern sites revealed that energy recovery rates exceed 70 percent.

Geological surveys, suitability criteria, and heat-exchanger designs were developed during the year, and environmental documents were completed. DOE is continuing to conduct site-specific studies, including aquifer testing, at three northern sites.

Energy Storage for Solar and Conventional Utility Applications

Energy storage can help solve the economic and operating problems facing electric utilities by leveling the electric load, allowing utilities to increase the substitution of coal- and nuclear-fired baseload generating plants for gas- and oil-fired peaking turbines. The storage device or facility can be located in the customer's home or place of business, at a central site, or dispersed throughout the system at substations.

Promising energy storage technologies for utility use include battery storage and compressed air and superconducting magnetic energy storage systems.

The Battery Energy Storage Test (BEST) facility being built in New Jersey will be a national center for testing and evaluating advanced batteries for load-leveling use on utility systems. Construction of the BEST facility began during the year and is virtually completed. The facility, which can simultaneously test three batteries of nominal 5-megawatt-hour capacity, is owned by Public Service Electric and Gas of New Jersey. It will test advanced batteries developed with funding from DOE, the Electric Power Research Institute, and other privately funded U.S. and foreign sources.

The first battery (zinc/chlorine) is being purchased. The Storage Battery Electric Energy Demonstration facility is being built by DOE, the Electric Power Research Institute, and several electric utilities. The intention is to develop a 30-megawatt hour (10-megawatt hour output) battery facility for on-line use.

In addition to utility applications, efforts are being made to use battery storage on the customer side of the meter. DOE and the New York State Energy Research and Development Authority are studying the economic feasibility of using battery storage to reduce peak electrical demand on the New York City subway system. Another effort will determine the economic feasibility of customer-side-of-the-meter battery storage at several sites.

Figure 6-3—Aquifer Seasonal Thermal Energy Storage. In this proposed energy storage system, heated or cooled water is pumped into aquifers and is stored until needed for heating or cooling. About 60 percent of the land surface in the United States is estimated to have aquifers suitable for energy storage.

Several utility companies are interested in compressed air energy storage systems, which can improve the efficiency of gas turbines. Gas turbines compress air simultaneously for their own operation and to generate electricity. In compressed air energy storage systems, these two functions are separate. Air would be compressed and held in underground chambers during off-peak hours and used to power gas turbines during peak hours. This eliminates the need to compress air for turbine operation during peak demand, allowing additional capacity to be devoted to the production of electricity.

The German utility Nordwestdeutsche Kraftwerke AG has been operating a first-generation compressed air facility in Huntorf, West Germany, for about 2 years. Similar plants in the United States are under consideration. DOE has funded preliminary design studies for three different

types of underground storage: caverns in salt domes, caverns in hard rock formations, and porous rock aquifers. First-generation compressed air plants require oil-firing to reheat the air as it is released through the turbines. With second-generation plants, as shown in Figure 6-4, original heat of compression would also be stored and then used to enhance the expansion of compressed air through the turbines, providing more efficient energy recovery without using additional oil.

Because of its high efficiency and quick response time, superconducting magnetic energy storage is a promising long-term technique for use at large central site facilities. Electromagnets—cylinders wound with conducting wires carrying electric current—can store electricity. At temperatures approaching absolute zero, certain conductors lose all electrical resistance to direct current, and the

Figure 6-4—Second-generation compressed air storage system

storage system is very efficient. A direct current at these temperatures will persist indefinitely and thus maintain its magnetic field.

A small superconducting magnetic storage unit that stabilizes transmission lines is now being constructed for the Bonneville Power Administration. The Los Alamos Scientific Laboratory directs the activity under DOE funding. It is to be installed on the Pacific Intertie, which connects Southern California with hydroelectric generating facilities in the State of Washington. The unit is expected to increase the line's useful capacity by 25 percent.

Improved thermal energy storage is being developed for six high-priority solar-thermal power applications. These include solar heat collection by central towers, troughs, and dishes. The emphasis is on second-generation storage prototypes for utility and industrial repowering experiments. In certain applications, solar photovoltaic power systems will require batteries for night and cloudy day storage. Small-scale battery photovoltaic systems are currently in use as part of the battery applications program. Studies are under way to develop large-scale systems using this technique.

Energy Storage for Industrial and Multipurpose Applications

Developments in 1980 in industrial and multipurpose applications include thermal storage components for retrofitting aluminum, paper, and food processing plants to recover reject heat, an efficient electrolyzer for producing hydrogen from water, and improved components for electrochemical processes.

Rejected industrial process heat can be captured and stored for subsequent use as space heat, process heat, or for electrical generation. Thermal storage for heat recovery is already in commercial use in some powerplants; DOE is providing information about these technologies to the pulp and paper industry. Demonstration sites have been selected for retrofitting processing plants with heat storage recovery units in the food and aluminum industries. The selected aluminum plant is expected to supply a community of 12,000 homes with heat at a lower cost than with conventional fuels.

Hydrogen is a nonpolluting fuel that has many potential uses as a chemical feedstock, as an alternative fuel for

transportation, and as a natural gas supplement. Currently, however, most hydrogen is produced using natural gas and oil feedstocks, and it costs more to produce than the fuels it could potentially replace. DOE is working to make hydrogen an economic fuel by using electrolytic and thermochemical methods. The electrolysis research and development is largely aimed at developing relatively inexpensive materials and catalysts that would use electrical energy to break water down into its components.

Thermochemical cycles produce hydrogen directly, avoiding the energy-wasting step of converting heat into electricity. Although thermochemical cycles are unlikely to be developed for large-scale use during this century, they hold great promise.

Hydrogen may eventually be produced at low cost for sale in nearby markets that use small hydroelectric power sources. The Department is continuing a demonstration project aimed at refurbishing a municipal small hydro source and connecting it with an electrolyzer to produce hydrogen as a chemical feedstock.

DOE is also supporting research and development in several areas involving the use of hydrogen as a fuel. Because the transportation application requires development of compact, safe storage, DOE is developing methods using high-pressure gaseous storage in microspheres and chemical storage in metal hydrides.

Development efforts focused on reduction of energy use in electrochemical processes have resulted in a new hydrogen electrode process for refining zinc ores; two industries are now cooperating in further development of this process. An air electrode for the chlor-alkali process has also shown considerable progress and is under continued development. The substitution of an air electrode for a conventional one saves 0.8 volt.

Outlook

The Department will continue its efforts to research and develop new technologies to ensure electric energy sup-

ply in the future. Each technology has individual characteristics and can be expected to interact with the existing or future electric network in different ways. Wind power's electromechanical response with the electric network will not be the same as that of photovoltaic, of ocean thermal energy conversion, or of geothermal. Therefore, each technology must be developed to produce optimum results on the electric energy system and provide maximum benefits and satisfaction to the end-user. EES research and development activities will provide important information in this regard.

Future activities in support of national energy policy will focus on three principal issues:

1. Ensuring that all elements of future electric energy systems are available and integrated to achieve an overall energy-efficient system
2. Developing the means of transferring large blocks of electrical energy interregionally to back up dispersed sources and to meet normal and emergency needs of the future network. Meeting this goal involves overhead and underground HVAC and HVDC systems. The focus of this area will be on the terminal conversion equipment and on a better understanding of the benefits and limitations of direct current transmission
3. Developing system design and control techniques that will maintain a high level of reliability as the system increases in size and complexity. Control systems are being sought to enhance the performance in all modes of operation, from normal to emergency to restorative states. The ultimate goal is to develop a computerized control system that automatically adapts itself to alternate modes of operation. Such a system will almost certainly have to be designed using new concepts

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Chapter 7

Environment

Introduction

To ensure that increased production and development of domestic energy sources is harmonized with protection of the environment and public health and safety, the DOE Organization Act mandated the Department "to assure the incorporation of national environmental protection goals in the formulation and implementation of energy programs, and to advance the goals of restoring, protecting, and enhancing environmental quality, and assuring public health and safety." To ensure that these objectives are met and that all environmental laws and regulations are complied with fully is a responsibility shared jointly by the Office of Environment and various energy program offices, including fossil, nuclear, and conservation and solar energy.

As coal, synthetic fuels, solar, nuclear, and alternative energy technologies become attractive energy alternatives, environmental health and safety factors must be balanced with technical and economic considerations. Environmental impacts created by new energy technologies must be identified early so that mitigating strategies can be built into all phases of development, from design through commercialization. The Department, under the guidance and direction of the Office of Environment, conducts a comprehensive research and assessment program designed to achieve this goal. The Office of Environment, organized to maintain the necessary linkage between its activities and those of the technology program offices, concentrates its efforts in three major areas—environmental assessments, biological and environmental research, and environmental compliance and overview.

Environmental Assessments

The Environmental Assessments program evaluates how environmental issues, laws, and regulations might affect energy development and use, and how energy plans and programs might affect the environment, health, and safety of the Nation. Through different regulatory, technological, and regional assessments, this program analyzes the impacts of energy-related environmental policies, identifies potentially adverse impacts of developing energy technologies, and proposes measures that could be used to mitigate those impacts.

Regulatory Analyses

Analyses of the energy-related implications of proposed and existing Federal and regional environmental and safety policies, laws, and regulations enable the Department to make informed decisions on environmental issues, to formulate balanced policy positions, and to evaluate environmental and safety regulations and standards proposed by other Federal agencies that may significantly affect energy development and widespread deployment of energy facilities.

Analyses of the issues associated with developing and emerging technologies typically include air quality, water quality, and transportation. For example, assessments disclosed potential air emission problems associated with the increased use of fuel-efficient diesel engines in passenger car and light truck fleets; as a result, the Department initiated a program during 1980 to evaluate the health risks associated with diesel exhaust emissions. The

Department also began analyses of water-effluent guidelines for steam electric powerplants, for petroleum refining, and for coal and ore mining. In 1981, evaluations will continue on the impact of the Clean Air Act, the Clean Water Act, and the Surface Mining Control and Reclamation Act on DOE's policies.

As a result of legislative initiatives for synthetic fuels production—notably the Energy Security Act of 1980—the Department initiated detailed environmental and regulatory analyses of synthetic fuels development. For example, a major analysis of the environmental and regulatory impacts on synthetic fuels production was published in 1980 and distributed widely to government, industry, and environmental groups. This report (entitled *Synthetic Fuels and the Environment: An Environmental and Regulatory Impacts Analysis*) indicated that critical environmental constraints could be sufficiently resolved to allow the production of approximately 1.5 million barrels per day by 1995 of synthetic fuels from coal, shale, and biomass. Achieving this goal, however, assumes that the most effective environmental control technologies and practices are applied in new facilities, and that operational monitoring information is fully utilized to identify and resolve unforeseen problems and uncertainties. The report concluded that the greatest area of uncertainty is the potential impact of yet-to-be-promulgated regulations.

Technology Assessments

The Technology Assessments program identifies potential problems associated with energy technologies early in the research and development stage and monitors these problems as the technology develops. Four major sets of documents—environmental development plans, project environmental plans, environmental readiness documents, and technology assessments—supply information for planning and management decisions on technology research and development.

Environmental development plans and project environmental plans, prepared jointly by the Office of Environment and energy program offices, ensure that environmental, safety, and health concerns are adequately addressed during the technology development and demonstration stages prior to commercialization. These plans define research needed to resolve concerns before a technology is commercialized, and they coordinate research and development schedules. Early planning reduces the likelihood that adverse environmental effects will be discovered after costly commitments have been made to a technology.

In 1980, major revisions were completed on 30 environmental development plans initiated in 1977. Each update provides a clearer delineation of the additional research required to make a technology environmentally

acceptable. For example, an environmental development plan examining a technology for the underground gasification of coal—perceived as an environmentally attractive method of producing synthetic gas—identified such potential problems as pollutants from the coal steam contaminating ground water and the possibility of noxious gases escaping into the atmosphere. Plans have been established for other synthetic fuels processes, including coal-derived liquids and shale oil, for advanced isotope separation, and for conservation programs.

Environmental readiness documents, based on analyses of available environmental research, are independent assessments by the Office of Environment of the potential environmental risks and impacts associated with energy technologies at key decision stages of development. Such assessments, developed with a consistent analytical format, provide DOE decision-makers with an objective, rational means for determining whether a technology is ready from an environmental perspective for commercial exploitation.

Since 1978, 30 technology systems have been documented. During 1980, environmental readiness documents were initiated to assess such diverse systems as magnetohydrodynamics, indirect coal liquefaction, and alcohol fuels from biomass. This program will be continued in 1981, and updates of several key technologies will be completed.

Technology assessments are another class of analytical studies designed to evaluate the future environmental consequences of various energy systems. Each study is individually designed to include information such as the nature of the technology system, its role in the total energy system, and geographic considerations. In 1980, assessments of several major technologies were nearing completion. An assessment of solar technologies indicates that some solar energy systems could have potentially significant adverse effects on the environment. An assessment of geothermal energy indicates that geothermal resources in California can be developed in a way that is compatible with agricultural production. An oil shale study is defining critical issues surrounding this controversial technology and establishing the analytical framework for a continuing assessment.

Several other assessments that are in progress will be completed in 1981. These studies will provide baseline data for analysis of the major energy systems, which can be updated as field experiments generate new data.

Regional Assessments

The Regional Assessments program was established to determine the impact of energy technologies and programs on land, water, and air quality, on human health and safety, and on social and economic systems within pa

ticular regions of the country. To identify and quantify the potential environmental and socioeconomic impacts of supply and demand projections for various energy sources, the Department prepares regional issue identification and assessment reports covering important and pressing issues. State-by-state assessments of potential environmental impacts of increased coal use, for example, suggest that the second National Energy Plan was overly optimistic in its projections of powerplants switching away from using imported oil. In most states, switching electric utilities and industries from oil and natural gas to coal requires large expenditures for air pollution control and long periods of time for air quality analysis to ensure that air quality is not degraded.

Other assessments have concluded that in many plains and western states, coal-, shale-, and grain-based synthetic fuel productions will compete strongly for both land and water resources currently dominated by traditional agricultural uses. The development of synthetic fuels complexes must proceed with caution to avoid adverse economic impacts that could generate local resistance to meeting planned industrial capacities. In addition, many areas of the West will be subjected to surface mining of coal and shale, with continuing debate over the success of reclama-

tion programs. As the resources of one region are extracted, processed, and shipped for the benefit of others, interregional conflicts will require resolution.

These and other regional assessment issues are under continuous review to ensure that barriers and constraints to implementing national policies are identified, and techniques for mitigating problems are developed.

Biological and Environmental Research

The Biological and Environmental Research program supports research in the areas of human health, health effects in biological systems, carbon dioxide and climate, pollutant characterization and monitoring, and health effects risk analysis. Research in these program areas identifies and quantifies potentially hazardous energy-related pollutants. Much of this research is devoted to developing specialized instruments for detecting and measuring pollutants; predicting, usually through computer models, the types and quantities of hazardous materials or situations that are likely to result from commercialization of a technology or resource; and evaluating the impacts, both beneficial and detrimental, that these materials may have on humans and the environment. (See Figure 7-1.)

Figure 7-1

Data collection from rain gauges and wind-measuring devices to determine atmospheric effects of thermal energy releases.

Research is conducted on all natural systems likely to be affected by emerging or expanding technologies, including laboratory and field studies of terrestrial and marine ecosystems and epidemiological studies of humans to identify the potentially harmful effects of energy-related pollutants. Applied research includes studies that examine the response of biological systems to a specific pollutant in order to establish a dose-effect relationship and the onset of diseases such as cancer. Biological and environmental research programs generate information that leads to integrated analyses and assessments of overall health, environmental, and safety impacts of technologies, and enhances the ability to predict these impacts. This information is used to provide technology development programs within DOE and researchers outside DOE with an understanding of what needs to be done to reduce or prevent potentially adverse effects of developing technologies.

Major program activities in 1980 focused on research to determine the health and environmental effects of fossil energy-related pollutants, especially those associated with the production of synthetic fuels from coal and oil shale; conservation options, such as the use of alternative (diesel) fuels and insulation practices; carbon dioxide and climate research; and the effects of low-level radiation exposure. Additional activities included conducting studies at selected technology demonstration facilities to define environmental considerations that may be associated with commercialization; and research to improve health protection techniques and instruments.

Fossil Energy

Coal will play a major role in meeting the Nation's energy needs. Research to determine the health and environmental impacts associated with conventional and advanced coal combustion technologies is a high priority in the Biological and Environmental Research program.

Significant environmental concerns generally associated with synthetic fuel processes include air and water quality degradation, disposal of by-products and solid waste, and adverse health effects from occupational exposure to low levels of hazardous, toxic, or carcinogenic substances produced by synthetic fuels processes. Integrated biological and environmental research on synthetic fuels production is conducted in close cooperation with technology programs at the two solvent refined coal (SRC) pilot plants, the low-Btu gasifiers-in-industry demonstration plant, and the *in situ* coal gasification test project.

Current DOE research in coal combustion includes laboratory studies comparing the effects on health of emissions from direct coal-fired powerplants with the effects of emissions from plants using advanced processes such as fluidized bed combustion. To date, results indicate that

vapor-phase and particle-emissions from small experimental fluidized bed units are less toxic than those from conventional coal combustors. These findings are being validated at facilities where larger units are available.

Sulfur and nitrogen oxides in the atmosphere, some of which are the result of fossil fuel combustion, can combine with water to form acid rain. Acid rain has the potential to cause environmental damage, including increased acidity of lakes and rivers resulting in a decline in fish populations, possible damage to crops and forests, and deterioration of buildings and metal structures.

Although the Department has been studying acid rain since 1976, the causes, mechanisms of transport and deposition, and effects of acid rain are not fully understood at this time. In 1980, the Department developed numerical models to assess the long-range transport of sulfur pollutants. The Department also has studied the magnitude of transport of acid rain over Canada, as well as the incremental increase in air pollutants in regions that might result from the proposed Power Plant Fuels Conservation Act. DOE participated in the activities of an Interagency Acid Rain Coordination Committee that is developing the Federal Acid Rain Assessment Plan. These activities will continue under the Interagency Task Force on Acid Precipitation mandated by the Energy Security Act. In addition, DOE and the Environmental Protection Agency have established a joint working group to coordinate acid rain and technology-related research and development plans and programs.

In 1981, the research program in synthetic fuels will include an evaluation of the health effects of two additional coal liquefaction processes scheduled for pilot plant operation: the H-Coal and Exxon Donor Solvent facilities. The continuation of the SRC program and the addition of the two new facilities will provide a comparative evaluation of the health effects of the three major direct liquefaction processes scheduled for commercialization in the near future. Considerable effort also will be devoted to obtaining quantitative information on the early and late biological effects of potentially hazardous chemicals used in synthetic fuels production. The Department will continue investigations of the atmospheric transport and fate of pollutants from coal combustion facilities and the effects of acid rain on sensitive ecosystems.

Carbon Dioxide Research

Increasing levels of atmospheric carbon dioxide from the worldwide combustion of fossil fuels could affect the climate by raising the mean global temperature, which in turn could adversely affect agricultural productivity, aquatic and terrestrial ecosystems, and, ultimately, society. Research that provides reliable predictions of carbon dioxide buildup and its consequent effects is essential

to developing policies on fossil fuels. Research on carbon dioxide is being conducted by a number of Federal agencies and coordinated with other climate research by the National Climate Program Office. The Department of Energy is the lead agency under this program for stimulating and coordinating carbon dioxide research activities. The Department also directly supports ongoing carbon dioxide research and initiates activities in important areas not currently being investigated either in the United States or in other countries.

During 1980, a feasibility study was initiated to determine the possibility of using remote sensing methods to measure changes in global biomass and vegetation. This research will help determine whether the excess levels of carbon dioxide in the biosphere are a result of the combustion of fossil fuels or whether extensive land clearing, by removing vegetation, contributes to increased levels.

The Transient Tracers in the Oceans program, a multiyear research program supported jointly by the Department and the National Science Foundation, will examine atmosphere-ocean fluxes of carbon dioxide, the carbon geochemistry of oceans, and mechanisms for mixing carbon dioxide levels in surface and deep waters. Such information can help determine whether the oceans could be used as a natural "sink" for removing excess carbon dioxide from the atmosphere.

Initial results of the research on remote sensing methods and transient tracers in the oceans are expected in 1981. In addition, comparisons of historic relationships between levels of carbon dioxide and climatic conditions will be undertaken to verify climate models and to determine whether they would be useful in predicting future relationships. Finally, work will continue on an assessment of the entire carbon dioxide issue. This assessment, to be published in the "1984 Interim Assessment Report," will provide a comprehensive and authoritative basis for an energy policy that explicitly addresses the carbon dioxide issue.

Conservation

While most energy-conserving technologies tend to mitigate adverse effects on the environment by reducing energy consumption—thereby reducing the negative impacts associated with production or use—some conservation technologies create new environmental problems. Research conducted by the Department focuses on those technologies that are most likely to have significant effects on the environment, health, and safety, including light-duty diesel engines, alternative automotive fuels, urban waste as an energy source, and building insulation.

Diesel engines in light-duty vehicles are important conservation options because of their high fuel efficiency. However, light-duty diesel engines produce much greater

quantities of potentially hazardous particulate exhaust emissions than do conventional gasoline-powered vehicles equipped with catalytic converters. Physical properties and aerodynamic characteristics of diesel-engine particulate emissions have been evaluated over the past two years and correlated with the behavior of particulate material in the respiratory tracts of laboratory animals. Biological testing conducted in conjunction with chemical characterization has identified classes of particle-bound organic substances that exhibit strong mutagenic and carcinogenic properties. DOE also has conducted extensive research to determine how engine operating variables may affect the output of particle-bound toxic agents in diesel emissions. These ongoing studies will yield more clearly defined health risks for exposure to diesel particulates and may contribute to the development of measures to control releases of highly toxic substances.

Related information is being generated by recently initiated research on the transport and fate of diesel exhaust emissions in the environment and on the lifetime health effects on rodent populations from continual exposure to graded levels of diesel exhaust emissions. The first in a series of health risk assessments currently is nearing completion. It is expected that all ongoing studies will continue in 1981.

DOE also is studying the potential adverse effects from large-scale production of ethanol and methanol and from their use as alternative automotive fuels. For example, the potential effects of evaporative and exhaust emissions from alcohol fuels on air quality and human health are ill-defined. To obtain additional information, the Department has conducted research for several years on the character and quantity of both evaporative and exhaust emissions produced by ethanol or methanol used in automobile engines. This study, evaluating both alcohol-gasoline blends and unblended (neat) alcohols, is providing quantitative data on the output and composition of regulated and unregulated emissions under a variety of operating conditions. In 1980, DOE initiated two research projects to obtain quantitative data on health effects of alcohol fuels exhaust emissions as well as health effects associated with chronic, low-level exposures to methanol. These studies are expected to continue in 1981.

Urban solid waste traditionally has been an undesirable by-product of our society. The usual methods of disposal, such as dumping in landfills or in bodies of water, have created conditions that have adversely affected humans and their environment. The Department has two projects under way designed to assure mitigation of adverse environmental impacts when the energy potential of urban waste is utilized. The first involves an evaluation of the potential health and environmental effects of processing municipal solid wastes into refuse-derived fuel and the subsequent co-combustion of this fuel with coal in an

electric generating plant. The second project focuses on characterizing the emissions, effluents, and other residuals generated by an anaerobic digestion plant and determining the consequences of the interaction between these materials and the environment.

The increased use of insulation is a conservation measure that may create additional health-related problems. Epidemiological information to date indicates that asbestos, commonly used for insulation, can cause lung cancer in humans; limited data from animal studies tend to confirm this. The Department is conducting additional animal studies to determine the lifetime carcinogenic effects of asbestos. These studies are expected to continue in 1981.

An attendant concern with the increased use of insulation in buildings is the reduction of the rate of air exchange between indoor and outdoor. The Department is supporting ongoing studies to identify all significant indoor air pollutants and their sources and to evaluate the potential health risks associated with increased pollutant levels in energy-efficient homes. Such studies are providing information that may be useful in developing methods of controlling indoor air pollutants.

Nuclear Energy

Like coal, nuclear energy can play an important role in the Nation's energy future, and continued research must address the environmental, health, and safety risks of low-level radiation. Emphasis in research is placed on developing techniques for measuring the low-level radiation doses powerplant workers or the general population may be exposed to during routine operation of nuclear powerplants or from nuclear accidents; evaluating the real or potential risk to human health associated with such exposures; and developing the capability to respond to emergency situations such as the one that occurred at Three Mile Island.

New and improved instrumentation and analytic methodologies are being developed for evaluating radionuclide concentrations and distributions in the workplace and in the general environment. For example, state-of-the-art soil sampling and radiation measurement techniques were used to evaluate the levels of radiation from the Three Mile Island reactor incident and from past nuclear testing at the Nevada Test Site and in the Marshall Islands. Improved instruments, methodologies, and calibration techniques are essential for the quantitative assessment of the radiological impact of the construction, operation, and decommissioning of nuclear facilities and for the validation of models used in these assessments when relevant measurements are not available.

Extensive research efforts are under way that will provide data on genetic changes in various animal, cellular, and molecular systems and latent biological effects of low-

level radiation. Such data will permit a quantitative assessment of potential carcinogenic and mutagenic risks to humans. The research program also supports a limited number of important epidemiological studies of people who were exposed in the workplace to radioactive nuclides. These include an investigation of the health status and mortality rate among employees who were exposed to low levels of external radiation in DOE facilities at the Naval nuclear propulsion shipyards. Also supported are continuing studies of non-DOE employees who were occupationally exposed some years ago to radium as well as studies of persons who were exposed to thorium for therapeutic reasons.

In addition to studies of occupationally exposed individuals, important epidemiological studies of two nonoccupational populations have been conducted for many years. The first is a long-term study to determine the adverse effects of radiation on the health and genetic structure of Japanese who survived the dropping of the atomic bomb. Studies of this population have been enhanced by a new approach for detecting genetic damage in the offspring of the exposed individuals. This approach uses red blood cells and serum proteins as specific gene-controlled markers through which changes in these proteins can be observed, identified as either new or old mutations, and, if new, related to the radiation exposure of the parent.

The second project is a continuing medical program for the inhabitants of several atolls in the Marshall Islands who were exposed to radiation from a 1954 nuclear test. (See Figure 7-2.) The Department supports medical care and treatment for radiation-related illnesses and, through radiological analyses, monitors the level of radiation in soils, lagoon water, seafood, crops, and air to ensure that it does not exceed acceptable levels.

In 1981, DOE will complete much of the research currently devoted to developing methods for measuring levels of plutonium and other transuranic radionuclides in the environment and in the human body. Research also will identify ways to apply similar techniques to measure levels of radium, thorium, and uranium used in other nuclear fuel cycles, and to measure levels of naturally occurring radionuclides from nonnuclear energy technologies such as coal mining and combustion and geothermal energy. New initiatives to develop dosimetric techniques for beta and neutron fields also are anticipated.

Environmental Compliance and Overview

The Environmental Compliance and Overview program includes a wide spectrum of activities that review, evaluate, and monitor DOE programs, facilities, and field operations to ensure compliance with Federal, state, and

Figure 7-2—Helicopter airlifting supplies to Ujelang atoll in the Marshall Islands

local environmental health and safety statutes, regulations, and standards; develop timely compliance guidance information that can be incorporated into DOE planning and decision-making.

Compliance with the National Environmental Policy Act

The National Environmental Policy Act (NEPA) established a national policy for the protection of the environment. NEPA requires Federal agencies to consider environmental factors in the decision-making process and to include a statement on the environmental impacts of major Federal actions that may significantly affect the quality of the environment. The Department's NEPA compliance program involves the development of generic environmental policy and guidance, and the review of specific DOE actions for compliance with NEPA and other related environmental statutes and regulations. This program is intended to meet national environmental protection goals while avoiding unnecessary delays in the development of energy initiatives and resources. Consideration of environmental factors early in the project planning process is an integral part of DOE's environmental compliance strategy to minimize delays and premature commitment of project resources, reduce the risk of litigation, and facilitate the project permitting process.

A major accomplishment during 1980 was the issuance of the DOE Environmental Compliance Guide which outlines procedures for complying with NEPA and other environmental statutes. This guide, along with a series of environmental, safety, and health training courses, has enabled DOE program managers to understand the entire environmental compliance process.

In addition, DOE developed strategies for the safe storage and disposal of high-level radioactive wastes and prepared environmental compliance plans for four major fossil energy projects. NEPA requirements, including environmental evaluation criteria and comparative environmental analyses, were developed for the synthetic fuels program. An analysis of requirements for DOE activities authorized by the Energy Security Act will ensure that such activities comply with NEPA.

Compliance with NEPA also is accomplished through the review of specific DOE actions. In 1980, the Office of Environment undertook 350 reviews that determined whether an environmental assessment or an environmental impact statement (EIS) was required for a proposed DOE action and outlined a strategy to allow orderly and timely compliance with environmental regulations. As a result of such reviews, documents are prepared that provide an analysis of the environmental impacts associated with a proposed project. In 1980, approximately 100 environmen-

tal assessments and environmental impact statements were reviewed and approved or disapproved for specific DOE projects. The Department anticipates that between 400 and 800 NEPA determinations will be prepared in 1981 and that between 150 and 200 NEPA documents will be independently evaluated and approved or disapproved. In addition, 1981 NEPA compliance activities are expected to include the development of a post-EIS monitoring system to ensure that mitigation measures are implemented during project development, the preparation of environmental compliance plans, and the development of other guidance as necessary.

Environmental and Safety Engineering

Because environmental controls allow energy systems to operate while minimizing environmental effects, the environmental and safety engineering activity is essential to the development of sound control technologies and strategies. Control technology evaluations are conducted on all energy systems, with special emphasis given to fossil fuels.

Interest in coal conversion technologies is shared by both public and private organizations. Previous environmental and safety engineering programs have helped identify key environmental control issues associated with these technologies that must be monitored as the technologies mature. Of particular concern is the confirmation of practical environmental control options required to deal with current and anticipated wastewater regulations and those solid waste regulations that may affect wastewater sludge disposal. In 1980, a workshop condensed the wide spectrum of environmental and safety engineering wastewater activities into a comprehensive status report that provides timely guidance to fossil energy research, development, and demonstration programs.

Near-term issues pertaining to industrial coal combustion will be investigated through assessments and data acquisition. These pursuits will yield detailed evaluations of the economic, engineering, and environmental trade-offs associated with various industrial coal options, including conventional combustion with stack gas cleaning, physical and chemical coal cleaning, and fluidized bed combustion.

Liquefied gaseous fuels such as liquefied natural gas (LNG) and liquified petroleum gas (LPG) could become a significant source of energy for the Nation. However, reliable information is needed to address concerns about potential hazards associated with storing, transporting, handling, and using these fuels. In 1980, the Department conducted experimental tests which indicated that heat radiation from LNG pool fires can approach levels up to twice those previously estimated. Moreover, anomalies in the results of actual spill phenomena exist when using dif-

ferent quantities or different atmospheric conditions since there is no set model for predicting the possible impacts of larger spills. The second finding emphasizes the current lack of understanding of how spill size may affect public safety considerations. Technical information required to identify the safety and control issues for these fuels will continue to be collected in 1981, with emphasis on further delineating the behavior and safety impacts for an LNG spill of a more realistic size.

The Department's 1981 environmental and safety research in the areas of solar, geothermal, and conservation will include several activities. For example, field data on the environmental acceptability of waste disposal methods from small-scale gasohol units will be acquired and evaluated, and the management of hydrogen sulfide emissions from geothermal operations in the Geysers region will be assessed.

In carrying out responsibilities for cleaning up sites and facilities contaminated by nuclear operations conducted for the Government, DOE conducts aerial and ground radiological surveys to determine the nature and extent of contamination at these sites, and independently evaluates and approves plans for remedial action operations. In 1980, DOE prepared reports and surveys that indicated that radiation levels at various sites were above the guidelines established by the Nuclear Regulatory Commission, the Environmental Protection Agency, and DOE. As a result of these elevated radiation levels, the Department formulated a schedule for conducting remedial action at these sites. In addition, DOE conducted independent measurements of the remedial action at four sites in Middlesex, New Jersey, and one site in Jersey City, New Jersey. As a result of survey data furnished by the Department, 25 properties in the vicinity of Canonsburg, Pennsylvania, and 2 in Salt Lake City, Utah, also have been designated for remedial action. Further designation as a result of the surveys conducted during 1980 will continue in 1981. In addition, radiological surveys will be conducted in 1981—both during and after remedial operations—to certify that cleanup is in compliance with applicable requirements.

As required by the Uranium Mill Tailings Radiation Control Act of 1978, DOE worked jointly in 1979 and 1980 with several states to establish programs to control radiation from inactive uranium mill tailing sites. In accordance with the provisions of this act, the Department established a cooperative agreement with Pennsylvania that establishes procedures for implementing remedial action. Utah also is concerning such an agreement.

In 1981, the radon monitoring program will be expanded to include additional mill tailings sites and to determine if areas near these sites require remedial action. The Department will identify and evaluate potential remedial

action techniques for ensuring the environmental acceptability of low-level radiation hazards from these areas. The most promising alternatives will be recommended for further development.

Operational and Environmental Safety

The Operational and Environmental Safety program ensures that the Department's activities and facilities, as well as those of its contractors, comply with DOE environmental, health, and safety policies and other applicable Federal, state, and local policies, standards, and regulations. This year, the Department continued to implement, review, and revise policies, and to appraise field activities in light of these policies. In 1981, DOE expects to conduct applied research to develop environmental, health, and safety performance measurement systems and standardized procurement procedures for DOE contracts. In addition, specific quality and reliability assurance policies will be prepared in 1981 to support major energy systems acquisitions.

Efforts to identify the potential health and industrial hygiene problems of personnel employed in various experimental and demonstration plants continued in 1980. This activity, along with studies to evaluate toxic materials in the workplace, will provide baseline data in 1981 for establishing industrial hygiene guidelines for DOE facilities that use substances previously unknown or not used in large quantities.

The Department provided the primary emergency response at Three Mile Island, and the experience led to reinforced efforts in 1980 to ensure that DOE radiological emergency plans were in effect at all DOE sites. In response to the Three Mile Island incident, the Interagency Radiological Assistance Plan was revised. It was recognized that DOE's unique aerial measuring and-atmospheric release prediction systems should be more accessible to industrial and state organizations.

Outlook

The Department will continue to analyze environmental policies, laws, and regulations that affect energy development and use. Increased emphasis is expected to be placed on assessing evolving energy technologies, synthetic fuels production, and the siting of new energy systems; and analyzing the impact of long-range air pollution for major geographical areas.

Research to determine the health effects of synthetic fuels and other developing technologies is expected to receive additional emphasis, as is research and evaluation of the long-term effects of carbon dioxide on climate, environment, and socioeconomic concerns.

The development of more systematic analyses and assessments should improve DOE-wide compliance with NEPA and other Federal and state environmental statutes. This will require training those DOE program managers responsible for NEPA compliance and continuing to develop policies, procedures, and administrative regulations that ensure that NEPA requirements are included in program planning and procurement processes. In the area of environmental control technology, the Department's plans for 1981 include assessing control technologies for industrial coal use, synthetic fuels production, liquefied gaseous fuels, oil shale, and continuing surveys of nuclear-contaminated sites and facilities.

Overall, DOE will continue to identify and address environmental, health, and safety concerns associated with developing energy technologies. As priorities change among technologies and research begins to answer some of the existing environmental questions, the focus and direction of these programs will change accordingly. What will remain constant, however, is the commitment to provide environmentally acceptable energy technology choices for the future.

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Chapter 8

Energy Supporting Research

Introduction

The Department of Energy carries out a wide range of scientific research that provides a basis for the development of new energy technologies and the improvement of existing ones. This research helps to determine the economic feasibility of new energy-producing processes and identifies and resolves the inherent problems of new and existing technologies. Such research is crucial to the Nation's future because it leads to the more effective and environmentally acceptable use of resources and to advances in energy production and conservation that are necessary to meet national energy goals.

While some of this research is carried out under individual technology programs within the Department, the largest and broadest effort is the Basic Energy Sciences program within the Office of Energy Research (OER). Research supported by this office cuts across the missions of technology development programs and contributes to a multiplicity of departmental and national objectives. It also contributes directly to the science and technology base drawn upon by the private sector in developing and demonstrating energy technologies.

Through its technical assessment and planning efforts, the Department of Energy assesses the adequacy of applied and basic research activities carried out by existing

Department research and development programs. It also conducts a program aimed at identifying and taking advantage of promising new technology projects.

Federal support of this scientific research is particularly important since its long-term nature and wide range of applications, some of which are not evident at the outset, do not lend themselves to private sector support. Although industrial firms do perform some energy-related basic research for the Department, most research is carried out at universities and by the Department's multiprogram laboratories.

In addition to the significant amount of basic scientific research performed at universities, the education and training of scientists who will conduct short- and long-term basic and applied research in the future is important. OER's University Research Support program supports several activities to help maintain university resources and to create training opportunities for future scientists.

Basic Energy Sciences

Through its Office of Energy Research, the Department conducts a program of basic research in support of the Nation's energy options for the future. The research is long-range, and its major product is new knowledge of concepts, materials, processes, and techniques which are important for energy production, conservation, and use.

Although the program is balanced and includes research relevant to all energy production and conservation technologies, most of the specialized programs are carried out along disciplinary lines. These programs include materials sciences, chemical sciences, nuclear science, engineering, mathematical and geosciences, and biological energy research. An advanced energy projects activity that crosscuts disciplines is also included.

The primary benefit of research in these disciplines is the increased knowledge of basic processes and properties on which applied technologies rest. However, direct commercialization of research results does occur. For example, industry is finding diverse applications for the newly developed ion implantation and laser annealing techniques. More than 20 U.S. companies have established capabilities in this area, especially in relation to new solar materials and the alteration of surface properties that affect wear and friction.

In a second example, basic research in analytical spectroscopy has led to a remarkably effective instrument that can detect and measure more than 40 chemical elements simultaneously. Competition in manufacturing this instrument is growing rapidly, with current industrial sales ranging between \$20 million and \$40 million annually.

During the year, research activities were carried out at approximately 165 institutions in over 40 states and the District of Columbia. Over 2,000 scientists and engineers were supported at the DOE multiprogram laboratories, at universities and, to a lesser extent, in industrial firms.

Many of the scientific fields comprising these research efforts require large, expensive, centralized facilities. At the Sandia/Livermore Laboratory, construction of the Combustion Research Facility was completed and is scheduled to be dedicated in 1981. A detailed, scientific understanding of combustion is a key element in improving the efficiency of all fossil energy-based systems and in controlling the formation of pollutants. This facility will provide unique capabilities for advanced physics and chemistry research on the kinetics, diagnostics, and theory of combustion processes occurring in engines and furnaces.

At the Brookhaven National Laboratory, construction of the National Synchrotron Light Source, begun in 1978, is expected to be completed in 1982. This \$24 million facility will provide the highest intensity pulsed X-rays and vacuum ultraviolet light available for advanced research on structure at the molecular and atomic levels in materials, chemical, and biological sciences. Ultimately, it will provide the United States with a unique facility that will contribute to developments in instrumentation, electronics, communications, computers, and catalysis. Further information on the Brookhaven facility can be found on page 104 of Volume III, *Project Summaries*, of this report.

The following sections describe the kinds of research carried out under each program as well as some significant research results obtained in 1980.

Materials Sciences

Research conducted under the Materials Sciences program is aimed at understanding materials properties and phenomena intrinsic to all energy systems. Materials often are the key limiting factor in the development of new systems, the performance of present systems, and the evolution of advanced concepts. In the Materials Sciences program, emphasis is placed on known or anticipated problems and on areas where significant improvements in performance and, therefore, economics depend on the selection of materials and design.

The Materials Sciences program includes work in metallurgy and ceramics, solid state physics, and materials chemistry. Some of the research is important primarily to a particular energy technology (for example, studies of catalytic materials of interest to coal conversion), while other research is applicable to many technologies (for example, studies of brittle fracture of structural materials). In addition, fundamental research in such areas as neutron scattering is under way, which can ultimately serve as the foundation for future technologies. This kind of research often requires the unique facilities and expertise available only at DOE laboratories.

The connection between materials research and technology development is vital to the selection of research projects to be supported and to the effective use of research results. In 1980, the Materials Sciences program identified research needs in important new areas. Activities included a meeting of the program's contractors on the physical and mechanical properties of coal, a conference on alternative "host" materials for nuclear waste products, panel meetings on nondestructive evaluation and on amorphous alloys, a workshop on materials interface problems as they relate to solar energy, and several research assistance task force meetings among basic researchers and technologists to discuss specific materials problems. During 1980 these task force meetings addressed the subjects of canisters for nuclear waste disposal, materials for Stirling engines, and metal/air batteries.

Also during the past year, the results of a number of research tasks added to available data on materials properties behavior and yielded new discoveries or concepts. Some of these results found early application in applied technology development or even commercial activities. The following paragraphs illustrate some of these accomplishments.

The release of fission-product iodine as the result of a reactor meltdown is currently considered to be one of nuclear power's most serious threats to public health.

fission-product iodine is highly radioactive and it is concentrated by humans in the thyroid. It was assumed in the past that virtually all of it would be released to the atmosphere if fuel element meltdown occurred. Continuing thermodynamic studies predicted that the chemical form of fission-product iodine in light-water nuclear reactor fuel rods should be chemically bound as an iodide, probably cesium iodide, and not as molecular iodine as previously assumed. Stimulated by these studies, tests of irradiated commercial fuel rods were carried out under Nuclear Regulatory Commission sponsorship, and the prediction based on the thermodynamics studies was verified. The prediction, now bolstered by direct experiment, is in accord with the behavior of the reactor at Three Mile Island, where the observed release of iodine was only about one-millionth of that expected. This finding substantially improves our capability to predict the consequences of reactor accidents and could have a major effect on nuclear plant siting criteria and accident response procedures.

Reduction in the weight of new automobiles is providing a major contribution toward reduced fuel consumption per mile driven. Safety considerations, however, call for maintaining adequate strength and fracture resistance in the automobile structure. The strength and fracture resistance of different types of steels depend on the structure and distribution of the phases of iron present—in this case, ferrite and martensite. The composition of these phases in steel was studied using advanced electron microscopy capabilities uniquely available at Lawrence Berkeley Laboratory.

Information gained from these studies made it possible to optimize the structure of steel for strength and fracture resistance. As a result, a new class of steel alloys has been designed with greater strength and fracture resistance per unit weight than steel currently in use. These alloys, called "dual phase," can be fabricated using current commercial methods. The annual energy savings possible through weight reduction by using these dual-phase steels in cars, trucks, and trains may approach 10 percent of the 20 quads currently consumed by the transportation sector.

Researchers at Oak Ridge National Laboratory have used two advanced materials characterization techniques to determine in a nondestructive way the size, shape, and amount of oil-bearing pores in oil shale. Using neutrons from the High Flux Isotope Reactor, information on the total pore distribution was obtained by small-angle scattering of the neutrons. X-ray small-angle scattering was used on the same sample to determine the pore distribution for empty pores. The difference between the two sets of data provides information on oil-bearing pores. This technique demonstrates the capability to obtain highly complex information on a material accurately and quickly. In the case of oil shale, this information is important not only for

determining the oil content, but also for choosing the recovery method.

Based on research done at Lawrence Berkeley Laboratory, a portable device known as the SQUID (Superconducting Quantum Interference Device), capable of detecting very small changes in the Earth's magnetic field, has been built to search for geothermal fields. The detectable changes in the Earth's magnetic field are in a range that may be a result of the presence of water or oil. In recent field studies in Mexico, measurements in a known geothermal field revealed potentially extensive new geothermal sources along a fault line; Mexico plans to drill in this area for confirmation. The application of this portable device in searching for geothermal fields resulted from research related to the quantum theory. The extreme resolution of the SQUID apparatus permits measurements at the limit of current theory and may lead to further refinement or verification of quantum theory as it is understood today.

The properties of many materials are strongly affected when hydrogen contacts their surfaces or diffuses into them. Recent experiments at Brookhaven National Laboratory have led to a quantitative understanding of the rate at which hydrogen dissolves in metals. It has been demonstrated that thin layers of palladium on niobium metal dramatically increase hydrogen adsorption, with the significant result that every hydrogen molecule impinging on the surface splits into separate hydrogen atoms. The experimental results correspond to the surface reaction steps of adsorption and dissociation, being 200 times greater on a palladium-coated niobium surface than on clean uncoated niobium, and a similar enhancement of the permeation of the hydrogen atoms through the niobium. This work is expected to provide guidance for new catalyst development where an increase of 100 or 200 hydrogenation catalyst reactivity would constitute a breakthrough. The research is expected to affect hydrogen storage technologies, in which rapid hydrogen permeation into and out of materials is desirable, yet is limited by surface reactions.

A method has been developed to control the dihydride and trihydride content in amorphous silicon hydride for increased photovoltaic efficiency. The defect structure of silicon and the nature of the alloyed hydrogen determine the alloy's optical and electrical behavior that in turn governs its photovoltaic efficiency. It has been found that initial introduction of hydrogen into the amorphous silicon matrix forms a silicon monohydride, which has a good photovoltaic response. As more hydrogen is added, however, dihydride and trihydrides form that degrade the photovoltaic properties. Recent results have shown that the additional implantation of other elements, such as helium, can displace the hydrogen from the dihydride configuration to the monohydride defect, thus creating the

possibility for tailoring alloys for optimum properties.

In addition, superconducting materials have been created in which as many as one-half of the atoms were normally nonsuperconducting copper. These materials are composed of layers, only a few atoms thick, of different atoms that normally do not combine in a coherent fashion. Research on the synthesis of layered materials reveals that as the layer thicknesses are reduced and approach single atom thickness, the properties of the composite change dramatically. For example, an assembly of alternate layers of niobium with copper behaved as a homogeneous superconductor, although half the layers were normally nonsuperconducting copper. This technique offers the possibility of creating entirely new material with predetermined properties.

Research at the Lawrence Berkeley Laboratory aimed at understanding brittle fracture paths in steels and at developing alloying and heat treatments to avoid these paths has led to a new and promising class of cryogenic alloys. These alloys exhibit sufficient strength, fracture resistance, and formability for such applications as pressure vessels to contain liquid natural gas or support structures for superconducting magnets. The alloys are composed of ferritic steels containing manganese, but no nickel. This result may have wide-ranging implications for the control of intergranular failure in other steels damaged by improper heat treatments.

Radiation damage to structural materials in both fission and fusion environments continues to be an important research area. The ability to predict such damage and its effects after long periods of service is critical. With the aim of better understanding the mechanisms involved, the researchers in the program are working on developing techniques to simulate this damage in a controlled way. The phenomenon of "creep," deformation of the fuel rod cladding, observed with reactor structural materials exposed simultaneously to radiation and stress at high temperature, is being examined with ion simulation techniques at the Pacific Northwest Laboratory. It was found that the creep phenomenon is greater per unit of radiation received under cycling conditions—bursts of radiation interspersed with low exposure periods—than under steady conditions. A theory to explain this phenomenon is being tested. This insight is expected to be useful in both nuclear and fusion reactor design and development activities.

Chemical Sciences

Chemical changes play an important role in energy use and conversion, and the results of chemistry and chemical engineering research contribute to the scientific base across

a wide range of technologies. The new knowledge gain can be used in currently recognized problem areas, such as coal conversion, and in areas where technological barriers may as yet be poorly defined, as in the case of solar chemical cells. These results also can lead to entirely new technological routes to energy production. Increased general knowledge in the chemical sciences area results from this research, and most of the work under this program is relevant to energy-related goals. These goals include the economic production of synthetic fuels, the use of chemical reactions on catalyst surfaces to produce coal-derived fuels without undesirable chemical components, and the direct use of sunlight to promote chemical reactions to produce clean fuels (such as hydrogen).

Research in the chemical sciences concerns both the fundamental interactions which take place and the processes and techniques by which they occur. The fields of research include solar-related photochemistry, the chemistry and physics of combustion, fusion-related physics (nonnuclear aspects), chemical characterization and conversion behavior of coal, fundamentals of catalytic effects on forming fuels, chemical methods for separating useful from hazardous substances in nuclear or fossil technologies, analytical techniques, and basic chemical engineering including fluid and particle dynamics for improved combustion. Some of the results of activities carried out in these areas during 1980 are described below.

Catalysts have long been recognized for selectively increasing the rate of important chemical reactions, as in petroleum refining and exhaust gas cleanup. However, more information was necessary in order to exploit them for new uses such as the conversion of coal to liquid and gaseous fuels or to industrial petrochemicals. During 1980, a catalyst was discovered that allows the direct use of synthesis gas from coal as a reducing agent in place of hydrogen. The utility of this energy-saving and less expensive chemical reduction system has been shown in several important industrial processes, including the production of plastics and some of the manmade fibers.

Researchers at the Lawrence Berkeley Laboratory have discovered a photolytic process (water splitting) that yields gaseous hydrogen and traps the active oxygen produced by the process in a form that has great potential for certain large volume industrial processes. Photolytic reactions induced by sunlight in water normally yield atomic hydrogen and oxygen-containing species such as the hydroxyl radical. The hydrogen atoms produced combine to form gaseous molecular hydrogen, but if the oxygen-containing species is not readily removed from the system, or if it does not readily react to produce gaseous oxygen, the production of hydrogen will soon terminate. In water splitting, as in many other chemical reactions, the inability to remove a product from a reacting system results in th

buildup of species that cause undesirable reverse or side actions in the system. The discovery at the Lawrence Berkeley Laboratory results in a continuous process that overcomes this difficulty and yields hydrogen and usefully combined oxygen.

Also, a novel ion source has been developed that has potential application to fusion energy development. Ongoing work with the source is directed at the possibility that the collision of intersecting beams of clusters of deuterium molecules, when generated and accelerated to modest kinetic energies, may lead to thermonuclear reactions.

A new technique was devised at Argonne National Laboratory for separating from one another the microscopically distinct constituents of coal, called macerals. This technique is particularly useful in studying the chemical behavior of coal in liquefaction and gasification processes. Separating the macerals from one another to study their different chemical and physical properties has always been a very difficult and time-consuming process. This new technique is based on the observation that the swirling demineralized coal in a rotating stream of gas causes the particles to break each other apart. The collection of particles is then fed into a centrifuge in which the spinning canister contains a fluid with a stable density gradient such that the fluid becomes less dense at the center of the spinning bowl. The different macerals have different densities and each, therefore, "floats" to its own density level in the centrifuge. The fluid is then drawn off at the different density levels and the maceral fraction filtered from each level. By this method, macerals of over 90 percent purity have been obtained, with simultaneous information on the macerals' densities.

Chemical sciences researchers have developed new insight into catalyst regeneration for coal gasification. With this new understanding they have demonstrated that metal catalysts poisoned by sulfur can be regenerated far more completely than current practice achieves. This may significantly improve the economics of these catalyst systems for coal processing by extending the useful life of the catalysts and increasing the plant operating factor. The usual regeneration practice for removal of the chemisorbed sulfur has been to heat the catalyst in air in order to oxidize the sulfur to gaseous sulfur dioxide. Since the catalyst surface also becomes oxidized and catalytically inactivated, normal practice has been to follow up with a hydrogen treatment to remove the oxygen. Researchers demonstrated that in the air treatment, undesired oxidation of the metal surface proceeds faster than the desired oxidation of sulfur. Further, they showed that the competing oxidation rates can be manipulated to favor oxidation of sulfur over that of metal, by drastically lowering the oxygen concentration to 1-10 parts per million and by carefully controlling the temperature. The catalyst, generated in this way, regains nearly 100 percent of its

original activity. The concept may be applicable to other catalytic systems that are poisoned by sulfur.

The study of highly charged ions (atoms which have been stripped of most of their electrons) is important to the development of fusion energy because these ions may occur in fusion plasmas and may greatly deplete their energy. Until now it was possible to obtain such highly stripped ions in energy ranges far above those typical of fusion plasmas. Kansas State University physicists have devised a new method in which a beam of particles at millions of electron volts strikes a gas target, causing each gas molecule to lose many electrons. These highly charged ions emerge from the target at only a few tens of electron volts, an energy range previously unattainable for such highly charged ions. They are then accelerated to a few hundred electron volts for the fusion-related experiments.

As a result of measuring the isotopic (oxygen-18/oxygen-16) ratio in atmospheric carbon monoxide, Argonne National Laboratory researchers found that the amount of technologically produced carbon monoxide had increased over the past 8 years by an amount greater than that attributable to the internal combustion engine, which is the largest source of technological carbon monoxide. Possible explanations: a large increase from biomass burning which produces a carbon monoxide difficult to distinguish from internal combustion engine carbon monoxide, or a decrease in the atmospheric concentration of hydroxyl free radicals (OH)—the principal cleansers of carbon monoxide from the atmosphere. The first explanation does not seem likely since patterns of biomass combustion have not changed dramatically during the past 10 years. The second possibility is particularly disturbing because it could indicate an increase in pollutant trace-gas scavengers for OH, such as sulfur dioxide and nitrogen oxides. Research is continuing in this area.

There are aspects of combustion, such as the chemical specifics of carbon-containing fuels, that remain unknown and can affect fuel efficiencies. However, the study of carbon atom reactions has been hampered by the difficulty of getting well-characterized beams of single, unaggregated carbon atoms. Chemists at the Oak Ridge National Laboratory have recently developed a laser-based technique for preparing and isolating such beams and have used it successfully for studying carbon atom reactions with nitric oxide. This development lays the groundwork for future studies of similar reactions of carbon atoms and small aggregates in combustion systems.

Research on the mechanism of an important biochemical process has provided new thermodynamic insight into the possibility of attaining greater efficiency of energy utilization in complex chemical systems. Living systems derive their energy supply from the conversion of ATP (adenosine triphosphate) to ADP (adenosine diphosphate). ADP is converted back to ATP during

glycolysis, the process which converts sugars to oxidized chemicals during a multistep (nine or more) reaction.

The concentrations of the intermediates in the glycolysis process are observed to oscillate, with frequencies on the order of 1 minute, with definite relationships among the different intermediates' concentrations and their frequencies. A description has been developed demonstrating that oscillations in the multistep glycolysis sequence result in an increase of 10-15 percent in overall efficiency over that which would otherwise be observed. Essentially, this occurs because some of the energy that would be dissipated as heat is intercepted at peaks in the oscillations and appears as useful chemical energy. Although developed to explain the biochemical phenomenon observed, the description has been recast to provide additional insight into the thermodynamics of a heat (Stirling) engine as an example of the generality of this concept.

Nuclear Science

The Nuclear Science program includes basic nuclear research with low energy, light ions, neutrons, and photons; research into the chemical and physical properties of heavy elements; and the production and distribution of stable isotopes and special research materials. Important contributions are made by the Nuclear Science program through use of low energy light ion beams from accelerators and neutrons from research reactors. These particles are used to probe the atomic nucleus, to alter it, or to break it apart. Study of the changes to the nuclear probe after encounter with a nucleus and examination of the products of a nuclear reaction reveals information about actions within the atomic nucleus. Recently, at the Brookhaven High Flux Beam Reactor, experiments demonstrated a new theory, called the Interacting Boson Model, of the motion of particles in the nucleus. The success of these experiments was due in large part to the unique property of these slow neutron capture reactions uniformly to excite all the possible quantum states of a nucleus.

Research supported by the Nuclear Science program also serves nuclear energy technologies in more direct ways. For example, experimental research using neutrons and accelerated charged particles is being pursued to obtain data needed to support the fission and fusion programs. The evaluated data are used for a variety of purposes ranging from applications in nuclear medicine and fusion and fission reactor engineering design to use as a basis for regulatory decisions. An example of this research is the work performed at the Oak Ridge Electron Linear Accelerator in which nuclear data measurements were taken on 11 materials essential to the shield design of the Fusion Materials Irradiation Test Facility currently under

construction at Hanford, Washington. These new measurements provided data that were previously nonexistent and satisfied high-priority requests from the designers of this major new fusion facility.

A broadly based research program for studying chemical and physical properties of heavy radioactive elements, such as americium, curium, and californium, is also included under the Nuclear Science program. The study of the behavior of these heavy elements or actinides is important to the development of nuclear waste technology by predicting chemical behavior in the event of leakage of a storage container. It is also important to the synthesis of new and useful materials.

Recently, a new class of chelating agents was synthesized, one of which has been found to remove plutonium selectively from animal tissues. The chemical potentially offers a means of treatment for people exposed to plutonium. The immediate interest has been in the application of the newly synthesized chemical, Licam-C (linear catechoylamidic carboxylate), to living systems where it has been shown that one dose of Licam-C, with minimal side effects removed 70 percent of the plutonium from mice. Perhaps more importantly, this research also indicates the potential for producing tailor-made chemical extractants to treat both nuclear and chemical wastes to remove hazardous materials from stored wastes.

The Nuclear Science program provides support for a stable isotope separation program conducted at Oak Ridge National Laboratory. This program produces and separates a wide variety of stable isotopes for use domestically and internationally. These materials are sold for medical and industrial applications and research activities and loaned to research groups for nondestructive experimentation. For example, the isotope thallium-203 is used worldwide in the production of a radioactive scanning agent for the heart, and Oak Ridge National Laboratory is the sole free world source for this material. Sales of this one isotope amounted to more than \$1.2 million in 1980.

Engineering, Mathematical, and Geosciences

The Engineering Research program is aimed at advancing general understanding in many areas of research that are important to energy systems. Ongoing and planned research will enhance the ability to raise energy system efficiencies, to open new technology opportunities, to improve reliability, and to extend the life of energy systems. These research areas include (1) fluid mechanics relevant to such technologies as fluidized beds, slurry pipelines, effluent treatment systems, and geothermal brines; (2) heat transfer; (3) translation of laboratory technique

into practical field instruments and development of improved automated diagnostics for a wide variety of large-scale systems; and (4) development of critically evaluated data to support the scale-up of virtually every energy system, from batteries to fuel cells to coal liquefaction plants. The following accomplishments are illustrative of ongoing projects.

The fine-scale motion of turbulent fluids plays a crucial role in many processes involving mass and energy transport. During 1980, scientists advanced the mathematical theory of fluid turbulence, enhancing the ability to analyze spatial, momentum, and energy dynamics of rapidly moving fluids, such as those in heat exchangers, combustors, and other devices important in energy transfer. The fine-scale motion of turbulent fluids (on the order of millimeters) is of concern also in practical design applications because of the vibrations and noise generated in turbulent flow. This theory, with its improved mathematical insights, is expected to find applications in the design of more efficient and longer lasting components of energy systems.

In a separate project, scientists developed a practical formulation of thermodynamics and economics (thermoeconomics) to identify the best process paths when both energy efficiency and dollar costs are important design considerations. This formulation, applied to overall systems, can assist in both selective capital investment and operating changes likely to result in energy conservation and net reduced operating costs. A preliminary version of the method is already attracting interest from U.S. industry.

Last year, work proceeded on the development of a self-correcting, pipe-welding robot. If its demonstration is successful, this device could improve productivity and quality control in utility, construction, and process industries and at the same time enhance plant safety and longevity. During the past year, quantitative data were collected on the physics of the welding arc. Such new knowledge permits the development of an algorithm useful for development and implementation of this reliable, self-correcting, automatic welding system.

The Applied Mathematical Sciences activity is a focal point for advancing the state-of-the-art in mathematic, statistical, and computer sciences. Concepts, methodologies, and tools which can be used in the Department's energy technology and energy policy missions are being developed. These methods are the basic building blocks for large-scale computational models used to improve the efficiency and safety of energy systems by simulating, for example, fluid flows in hypothetical reactor accidents, enhanced oil recovery processes, automobile engines, and atmospheric pollutant transport processes.

Improving energy systems often depends on precise computation of systems behavior. The same types of com-

putation arise repeatedly throughout the energy field, and a major advance was made under the Applied Mathematical Sciences program this year in handling one of the most important types—called sparse, least square problems. More effective and realistic models will now be possible in analyzing, for example, the structural integrity of fusion reactors and the efficiency of combustion processes. This development came from new ideas on how to break down into simpler pieces the huge arrays of numbers that arise in these computations, and also on how to make optimum use of auxiliary computer storage, while avoiding the numerical instabilities that plague current methods. The new ideas have been incorporated into carefully constructed computer codes available to scientists and engineers throughout the Nation.

Another development was achieved by computer scientists at the Lawrence Berkeley and Pacific Northwest laboratories. This development introduces "compressed, self-descriptive" data storage schemes, which allow storage and retrieval of large data collections within the constraints of existing technology. These compression techniques are critical for the use of emerging technologies with the very large data collections typical of DOE's socioeconomic, environmental, and energy analyses. Self-descriptive schemes allow the analyst to retrieve subsets of very large data collections and organize them into a coherent data collection which may repeatedly be divided into smaller specific subsets and recombined without returning to the original or subsequent data collections—a major enhancement of the analyst's ability to focus on the data critical to his problem.

The Geosciences program—geology, geophysics, and geochemistry—involves nearly all phases of the energy utilization cycle, including exploration, extraction, powerplant siting, energy storage, and waste disposal. The broad scope and pervasiveness of the geosciences mean that the boundary between basic and applied studies is often indistinct. Geologic research is under way to locate and assess the magnitude of lava bodies and to better understand Earth movements that may affect choices of sites for geothermal energy or nuclear waste installations. Geophysics studies are being conducted on the behavior of rock under stress, and the thermodynamic properties of hot geothermal brines, and on thermal stress fracture. These studies include the development of techniques for extracting energy from lava bodies under the Earth's surface. Geochemistry work develops scientific bases for predicting effects like migration of nuclear wastes or brine in the Earth's crust. Several recent accomplishments are highlighted in the following paragraphs.

The eruptions of Mount St. Helens provided a unique opportunity for several geoscience research programs. Preliminary results of experiments at Sandia National Laboratory on volcanic gases show that the volatile con-

tents responsible for explosive eruptions may be relatively low. Volatile content has a large effect on magma viscosity, and this recently acquired knowledge will be useful in interpreting the geology of regions affected by recent or ancient volcanic activity. Other related geoscience activities include infrared photography and high altitude ash collection by the Los Alamos National Scientific Laboratory. The Pacific Northwest Laboratory also obtained an analysis of data on atmospheric transparency changes on a continental scale. These activities are particularly valuable to the Department of Energy's long-range studies of climatic change.

Energy deep within the Earth in the form of hot water, hot dry rocks, and molten rock constitutes a potential major energy resource. During the past year, four national laboratories—Sandia, Lawrence Livermore, Lawrence Berkeley, and Los Alamos—jointly completed a comparative site assessment for deep drill holes to study the thermal regime of the Earth. The study focused on the five most promising geothermal sites under which complicated magma-hydrothermal systems may exist. This site assessment is a significant step toward meeting initial DOE objectives in establishing a meaningful scientific effort on magma-hydrothermal systems.

In addition, Sandia National Laboratory has developed a mathematical code which effectively predicts the composition of gases from thermodynamic considerations in complex mixed systems at high temperatures. The code was developed to interpret volcanic gas compositions and tie them back to the energetics of the systems producing them, as well as to provide information on the geologic history of these systems. Understanding the energy-related aspects of volcanism is of particular importance in evaluating possible schemes for energy extraction from magma, and more generally, in gaining clearer insight into eruptive processes. A valuable spinoff of this work is the application of this code to the development of a titanium diboride coating resistant to erosion that is prevalent in coal conversion applications.

Biological-Energy Research

A program of fundamental biological research was established during 1980 with the ultimate goal of developing new knowledge on improved uses of biosystems both for conversion of the Sun's energy to production of biomass and for the efficient conversion of biomass to useful chemicals. The Biological Energy Research program focuses principally upon plant science and microbiological research.

Through plants, solar energy is converted to the chemical energy contained in biomass. Plant science studies generate basic information which ultimately may

affect net biomass productivity. This research is directed toward studies that could lead to more efficient trapping of solar energy and conservation of that energy by green plants (photosynthesis), enhancement of plant growth under suboptimal conditions, improvement of the quality of the biomass product, and reduction of energy inputs required for acceptable levels of productivity by plants.

Microbiological research focuses on the microorganisms that convert biomass into useful fuels and chemicals through the processes of degradation and fermentation. Chemicals such as methane and alcohol are considered important as potential fuels and chemical feedstocks. The objective of this research is to provide the conceptual base and groundwork for improved or novel microbial conversions of biomass to gaseous and liquid fuels and other chemicals. Areas under investigation include microbial degradative enzymes, microorganisms responsible for methane production, the genetics and fermentations carried out by microorganisms which grow in the absence of oxygen, the characteristics of thermophilic (heat-tolerant) and other microorganisms possessing attributes that may be used in future bioconversion technologies, and the cooperative interactions between different microbial species under controlled conditions permitting complex chemical transformations to occur rapidly and completely.

During the past year, 26 new research projects in the botanical and microbiological sciences were initiated. As part of the program's implementation, several workshops were sponsored to stimulate technical exchanges and clearly define high priority research needs. These workshops dealt with the mechanisms of water and salt regulation in organisms, the energy requirements for biological nitrogen fixation, the partitioning of carbon by the plant after photosynthesis, and the status of our knowledge concerning the genetics of anaerobic microorganisms involved in fermentations. The following describes accomplishments representative of the types of information emerging from the program.

Recent work at the University of Colorado has provided evidence that small polysaccharides (chains of sugars) act as regulators of plant growth and defense against attack by disease organisms. Plant disease-causing fungi and bacteria produce specific small polysaccharides that act as hormones (messengers) causing the plant to produce new antibiotics, preventive enzymes, and new growth, which block enemy attack. In addition, injury or trauma to plant cells causes release of specific enzymes that, in turn, release short polysaccharides from the plant's own cell wall. These cause specific changes in the plant, depending on the type of hormone released. This concept is novel and its application offers to explain some longstanding puzzles about the regulation of plant growth

and responses which ultimately relate to plant biomass production.

Researchers at Michigan State University have discovered antiflowering substances in plants. Previously, the prevailing idea was that flowering occurs when a flowering hormone initiates the process. More recently, the presence of antiflowering substances that can be transmitted through grafts has been shown. This advance sheds light on the chemical control over flowering and concerns biomass productivity since flowering can significantly reduce biomass production.

Also, progress has been made at Colorado State University and subsequently at the Solar Energy Research Institute in isolating microorganisms capable of synthesizing, from simple carbon compounds, hydrocarbons with a pattern of chemical composition resembling that found in petroleum. Some of these microorganisms can produce sizable amounts of hydrocarbons; however, these organisms are slow-growing. The discovery of the existence of organisms with this capability suggests that others with similar properties, but with more advantageous growth rates, might also be found or genetically tailored.

Advanced Energy Projects

This program supports exploratory research on new energy-related concepts that require proof of scientific feasibility and, where appropriate, an indication of economic feasibility. These concepts, which are at too early a stage of scientific definition to qualify for support by technology programs, are high-risk but have potentially high payoffs. Research is funded for up to 3 years to either prove or disprove the validity of the proposed new concept. Recent projects have included: new methods for direct conversion of heat to electricity, new methods for accelerating charged particles, new radiation sources with unusual characteristics (channeling radiation, X-ray lasers), extraction of oil from tar sands by radio frequency heating, new schemes for efficient heat engines, and exotic photovoltaic materials.

During 1980, results obtained under seven projects, originally sponsored by Advanced Energy Projects, were sufficiently promising for them to graduate from the program with the likelihood of funding for further work from other public or private sources. The following project is illustrative of both the Advanced Energy Projects program, itself, and of how the program helps to promote innovation.

A small business firm—four full-time and five part-time employees—received its first contract from Advanced Energy Projects to develop a new method of fabricating ohmic contacts for solar cells. The method, involving a

technique known as arc plasma spraying, appears to be extremely well suited for mass production of large area solar cells. After 2 years of Advanced Energy Projects sponsorship, the process was selected for technology development by DOE's solar technology program. Perhaps the most important accomplishment of the Advanced Energy Projects program is that, over the 3 years of its existence, it has established a programmatic home within DOE for innovative, far-reaching, untested, and risky scientific concepts which might otherwise be overlooked.

The importance of basic scientific research to the solution of long-term energy problems and, in a very real sense, to this Nation's ability to address a wide range of future problems cannot be overstated. In the next several years, these basic science programs will continue to turn out research results applicable to all of the energy technologies. Newer programs, including Advanced Energy Projects; Biological Energy Research; and Engineering, Mathematics, and Geosciences, will be enhanced. In addition, several specific research areas will be emphasized. These areas include high temperature materials research, the chemistry and physics of combustion processes, catalytic mechanisms and surface phenomena, photochemistry, and the synthesis of novel materials. In addition, an inertial plasma physics research activity is being transferred to Energy Research from Defense Programs in 1982.

Technical Assessment Projects

A number of technical, management, and technological feasibility assessments are carried out each year by the Department as part of the effort to provide the best combination of research and development programs to meet the Nation's energy needs. These assessments are supported by the Office of Energy Research in keeping with its legislative mandate to advise the Secretary on the Department's research and development programs. They are performed occasionally in collaboration with the Assistant Secretary for Policy and Evaluation and, at times, a perspective is sought from the private sector through the use of advisory committees.

In 1980, technical and management assessments were conducted on topics cross-cutting all the Department's activities as well as analyses of individual programs. The assessments activity also encompasses in-depth reviews of potential energy sources. In this regard, the Satellite Power System Assessment completed its third and final year of investigation into this novel concept for a post-year-2000 energy source. Of more immediate technological impact is the Advanced Technology Projects program which assesses the technological feasibility of innovative high-risk concepts.

Assessment Projects

An assessment of the Department's technology base was undertaken in 1980. The technology base includes the basic and applied research and the exploratory development carried out under each of the Department's technology development programs. An adequate technology base within each of these programs is essential to the successful demonstration and commercialization of all energy technologies.

Based on an analysis of information gathered from the Department's technology development programs, DOE laboratories, and other special studies, the Office of Energy Research developed a draft report (*Technology Base Review—1982*) on the current status and issues related to the Department's existing technology base. This report was reviewed by the Energy Research Advisory Board, a high-level, advisory committee to the Secretary. The Board completed an independent technology base review, and its recommendations (*Research and Development Needs in the Department of Energy*) are being considered and incorporated into the continuing Energy Research assessment. This assessment and accompanying recommendations will be considered by each of the senior departmental officials who comprise the Technology Base Council. This Council, established in March 1980 by the Under Secretary, is the formal mechanism through which the Department analyzes the quality, scope, balance, and budget of its technology base activities. The final Technology Base report and recommendations will be transmitted to the Under Secretary and will be used in preparing Department of Energy policy and fiscal guidance used in planning the Department's 1983 budget. In addition to the Technology Base assessment, the Office of Energy Research conducted a variety of additional technical assessments and planning efforts in 1980, including the following:

1. With the help of the Assistant Secretaries for Conservation and Solar Energy and for Resource Applications, the Office of Energy Research performed a management and technical review of DOE's electric battery and electrolytic systems programs. Departmental planners are using findings from the study in broadening the science base, adjusting project mix, and developing next generation battery systems having the requisite higher power and energy density.
2. Early in 1980, the Department of Defense and DOE embarked on a joint planning effort aimed at better coordination to ensure the availability of fuel to the Department of Defense as well as the efficient use of energy by that agency. A workshop was conducted on

March 10-12, 1980, that concentrated on transportation fuels, energy conservation, fossil fuels for fixed facilities, solar and renewable energy sources, and special projects which included small-scale hydropower, geothermal, and energy storage. The proceedings of this workshop and follow-on activities resulted in recommendations for approximately 60 coordination, construction, and research and development projects. One potential activity arising from this planning effort is a program to replace oil and gas used in Federal facilities with more abundant or renewable fuels. The program would be initiated first at the Department of Defense because that agency uses 85 percent of the oil consumed by Federal agencies for fixed facilities. Preliminary scoping shows a large fraction of these facilities can be converted in a cost-effective manner.

3. The Fossil Energy Research Working Group completed its assessment of long-range research needs in coal liquefaction, and recommendations were published in March 1980. They were used by the Assistant Secretary for Fossil Energy to establish research and development activities on coal conversion technologies.

Studies also were completed on synfuels, Ocean Thermal Energy Conversion, climatic implications of the buildup of atmospheric CO₂, and long-range weather predicting. Continued support is planned in 1981 for the Technology Base Review and cooperative activities with the Department of Defense, and assessments also are being planned for solar technologies, biomass, and urban waste programs. In addition, in 1982, a new Social and Economic Science program is planned to improve understanding of the basic social, economic, and behavioral factors affecting energy-related activities.

Energy Research Advisory Board

The Energy Research Advisory Board is the highest level advisory group within the Department. Through the Director of Energy Research, the Board advises the Secretary on overall research and development conducted by DOE and provides long-range guidance. Its membership is representative of the energy industry, universities, energy users, state and local governments, and public interest groups.

The Board's 1980 review of the Department's Magnetic Confinement Fusion program illustrates a typical review. The Director of Energy Research requested the Board to undertake an evaluation of the Department's Magnetic Confinement Fusion program and make recommendations concerning its future directions. The review, which began in February 1980, addressed a number of issues related to the pace, scope, and funding of the pro-

ram. In light of the rapid technological developments that have occurred in the Magnetic Fusion program over the last 2 years, the most basic issue was the choice of the next major steps to be taken in proceeding from the current generation of experimental devices toward generation of economic fusion power. A final report (*Report on the Department of Energy Magnetic Fusion Program*) containing the Energy Research Advisory Board's recommendations to the Department was submitted on August 28, 1980. Based, in part, on those recommendations, the focus of the program will begin to shift from experiments aimed at proving scientific feasibility to an engineering development phase.

In addition to the fusion review, the Board studied the Department's high-temperature geothermal resources development, gasohol, and hot dry rock programs, and its technology base activities. It also established a Solar Photovoltaics Energy Advisory Committee, as mandated by P.L. 95-950, the Solar Photovoltaic Energy Research, Development, and Demonstration Act, to advise the Secretary with respect to solar photovoltaic research and development.

During the coming year, the Board plans to establish a technical panel to study the Ocean Thermal Energy Conversion program. This is in response to P.L. 96-310, the Ocean Thermal Energy Conversion Research, Development, and Demonstration Act. In addition, the Board plans to continue reviews of DOE's solar photovoltaics, biomass, conservation, geothermal, and inertial confinement fusion programs as well as continuing to provide the review of the Gas Research Institute's research and development programs as requested by the Federal Energy Regulatory Commission.

Satellite Power System

The Department's assessment of the Satellite Power System energy concept continued in 1980. This assessment, initiated in 1977, began to deliver the final products for management review and a decision concerning how to proceed with investigation of the concept. This energy concept calls for the capture of solar energy by satellites which maintain a fixed position relative to Earth. The captured solar energy is then to be converted to electrical energy by means of solar cells or possibly thermal systems and finally to radio frequency energy and sent to Earth in a focused beam. The beam would be aimed at a ground receiving antenna where it would be reconverted to electricity for distribution in a utility grid.

The results of the 3-year, \$19.1 million Concept Development and Evaluation program are contained in nearly 100 research and assessment reports. These base data are summarized in four assessment areas covering systems definition and environmental, societal, and compara-

tive aspects of the Satellite Power System. The findings from these four assessments are summarized in a final report (*SPS-CDEP Assessment Report: Statement of Findings*) which describes the key systems and environmental, societal, and economic issues that must be considered in the policy formulation for future Satellite Power System research.

One of the unique aspects of the SPS-CDEP assessment is its work with the National Academy of Sciences (through the National Science Foundation). For example, the Satellite Power System microwave health effects program acted as a catalyst through the Academy in bringing together national and international experts on the health effects of long-term, low-level exposure to microwave energy. For the first time in this field, innovative theories are being explored and experimental designs are being outlined for international review.

Advanced Technology Projects

The Advanced Technology Projects activity provides DOE with the capability of identifying promising new technology projects in all energy fields and to modestly but rapidly scope and test innovative systems and components. Projects usually involve high-risk, high-payoff interdisciplinary or out-of-program technologies not addressed elsewhere in the Department. The Advanced Technology Projects activity develops engineering and economic data on these concepts and then, if promising, transfers them to other DOE organizations for further development.

An ongoing project to develop a novel residential solar energy system is illustrative of the kinds of projects carried out by the Advanced Technology Projects activity. This concept potentially could lead to a system that would produce up to 90 percent of a single family residence's total energy needs. Several aspects of the concept must be demonstrated, including high-efficiency photovoltaic cells, storage of electrolytically produced hydrogen in hydrides, and electricity production by hydrogen-driven fuel cells. So far, photovoltaic conversion efficiencies in excess of 12 percent have been shown for the silicon microspheres, and overall system efficiencies in excess of about 20 percent may be possible by using the heat from the fuel cell and the heat from the hydrogen-bromide solution bathing the silicon microspheres. As a result, the project has been transferred to the Department's solar program area for further development.

Studies were also carried out on a concept that would produce rapid methanization of coal as well as cogenerate electricity. The unique catalyst used in this gasification process has been tested fully over a range of engineering parameters, and lifetime stability has been demonstrated in a fluidized bed configuration. The project will be transferred to the Office of Fossil Energy in 1981.

In 1979, a rhodium photocatalyst using solar energy

to promote chemical reactions that reduced water to hydrogen and oxygen was demonstrated with a quantum efficiency in excess of 40 percent. In 1980, a substantially cheaper and more durable molybdenum/tungsten photocatalyst demonstrated overall efficiencies of 10 percent. This process could potentially lead to the large-scale use of hydrogen as a fuel or synfuel component.

Another major effort is under way for the recovery of oil from oil shale formations and tar sands through use of radio frequency heating. This process, illustrated in Figure 8-1, lowers oil viscosity sufficiently so that it can be extracted by conventional recovery methods. The efficiency and economics of the process are being measured in field demonstrations in Utah and Colorado.

Of potential significance to the electric vehicle program is a new concept being studied for an ambient temperature, rechargeable, high energy density, lithium battery that could allow a mid-sized vehicle to travel 300 miles between recharges. Engineering evaluations are being

performed on this new battery.

Two other projects—one for a variable transmissic... and inertial drive line system that could improve automobile mileage, and another that uses emulsified fuel mixtures to produce a cleaner burning fuel—have been started this year by Advanced Technology Projects and will continue into 1981. Other new projects involve a Stirling engine project to liquefy natural gas and solar magnetohydrodynamics cogeneration.

University Research Support

Along with the Department's laboratories, colleges and universities perform a significant portion of DOE supported research. During 1980, DOE obligated an estimated \$356 million in support of over 3,000 research projects involving university faculty and students. These projects ranged from research in the fundamental energy sciences underpinning the energy technologies to studies focused on

Figure 8-1—Hybrid tar sands radio frequency fuel extraction

longer-range options for future energy problems. An important element of this support is the training provided to students through participation in the research. These students, in turn, will provide the scientific and technical leadership of the future at laboratories, universities, and in other sectors of the economy. A related benefit is the expedited transfer of technology developments to the private sector through selected cooperative research efforts among universities, industry, and the Department's laboratories.

Of the Department's total research support to universities in 1980, approximately 45 percent was provided by the Office of Energy Research through its energy-supporting and basic scientific research programs. In addition, the Office of Energy Research is responsible for a University Research Support activity which provides a policy and management focus for longer-term university research and manpower development programs that cut across DOE program areas and the departmental structures of the universities themselves. The special-purpose programs which make up the University Research Support activity are the University Institutional Research program, the University/Laboratory Cooperative program, and the University Reactor Fuel Assistance program. The Department's Energy Manpower Assessment program will be included in this activity in 1981.

The University Institutional Research activity provides support for three types of research programs. The first supports campus-wide "proof-of-concept" and exploratory energy research projects which build on the existing scientific research capabilities at a small number of major research-oriented universities with significant involvement in energy research and development. These 3-year awards are based on a comparative review of unsolicited research proposals. This is the only departmental program that provides opportunities for universities to contribute to the national energy program on an institutional level doing research selected by the university scientists themselves. Ten institutional exploratory research awards are expected to be given in 1981, including two replacement awards for projects completed in 1980.

The second Institutional Research program supports energy research at smaller, traditionally minority universities and colleges. This program is aimed at strengthening the capability of these institutions to perform energy-related research and encouraging minority students to pursue scientific and technical careers in energy-related fields. Successful projects are transferred to the departmental technology program offices for further consideration and support. During 1980, 14 energy research projects were supported with minority schools, including a program at Jackson State University where researchers developed a new understanding of the fundamental mechanisms of energy transfer and collection in twin film solar photovoltaics

systems. This project has subsequently received follow-on support from the Solar Energy Research Institute.

The third Institutional Research program provided support in 1980 for summer research assignments at 10 DOE laboratory and contractor facilities for 250 minority high school students. The intent of this program is to encourage young minority students to pursue energy-related scientific and engineering careers by providing them with hands-on experience in energy research. Continued support in 1981 and 1982 is planned with particular emphasis on involving students in junior high school in energy-related research projects.

The University/Laboratory Cooperative program encompasses a variety of activities that bring college and university faculty and graduate and undergraduate students to DOE energy technology centers, laboratories, and other contractor-operated facilities to participate in ongoing research programs and intensive learning programs on energy-related topics. These activities take full advantage of the unique and specialized facilities and research instrumentation at the labs. Over 1,800 faculty and students participated in a variety of research and special education-related programs at these facilities during 1980. Such assignments often represented the only opportunities for faculty at smaller colleges and universities to contribute to energy-related research because of limited facilities and resources at their home campuses.

The University Reactor Sharing and Fuel Assistance Activity provides support to a small number of university nuclear research and training reactors for the fabrication cost of nuclear fuel, a portion of reactor operating expenses when the reactor is "shared" with neighboring institutions, and the handling of shipment and storage of spent fuel. Thirty-seven university research and training reactors currently are in operation. In 1980, 6 reactors were refueled, and funding was provided for 14 reactor sharing agreements.

Finally, the Department's Energy Manpower Assessment program is being transferred to the Office of Energy Research in 1981. The studies and assessments carried out by this activity will add to the Department's capability to project manpower availability at all skill levels for future energy research development and commercialization programs.

A closely related activity, the Energy Graduate Traineeship program, is a new initiative for 1982. These traineeships would be competitively awarded to universities and colleges with demonstrated research competence in energy fields where a potential shortfall of future professional-level manpower for research and operating programs is predicted. Among the fields that will be considered are fusion technology, nuclear engineering, energy-related health and environmental science, and chemical and mechanical engineering related to coal utilization, syn-

fuels development, and solar technology.

Outlook

The Department of Energy is committed to strengthening the base of scientific research and stimulating technological innovations that in turn will encourage the Nation's economic development and lead to improved energy supply and use. During the next several years, DOE will place emphasis on strengthening fundamental scientific research, establishing and expanding specific industry-related research programs that are vital to

many energy technologies, providing a scientific and technological base that will be needed by the private sector in meeting energy and other national needs, stimulating energy-related innovation and productivity, and enhancing the effectiveness of collaboration between academia, industry, and Government.

The Department of Energy recognizes that long-term, energy-related scientific research is essential to securing a prosperous energy and economic future for the United States. DOE science programs are, and will continue to be, vigorous and forward-looking.

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Chapter 9

Energy Production and Power Marketing

Introduction

The Department of Energy manages three principal energy production and distribution programs: selling and transmitting electric power through five Power Marketing Administrations, producing petroleum from the Naval Petroleum Reserves, and providing uranium enrichment services to domestic and foreign (free world) customers. The services and products that these three programs provide to the private sector are priced on the basis of cost recovery or, in the case of the Naval Petroleum Reserves, to obtain a fair market price. Revenues accruing from the Power Marketing Administrations and Naval Petroleum Reserves operations are returned to the Treasury while those from uranium enrichment services offset production costs. Table 9-1 is a summary of estimated gross energy production costs and revenues for the years 1980, 1981, and 1982. Revenue credits annually exceed budget authority.

Power Marketing

Five Power Marketing Administrations—Alaska, Bonneville, Southwestern, Southeastern, and Western Area—transmit and sell federally generated power in the United States. These Administrations market power in 33 states over 30,000 miles of transmission lines and account for approximately 6.5 percent of the Nation's electrical power. The geographical areas served by the Power Marketing Administrations are shown in Figure 9-1.

*Table 9-1 — Gross energy production costs and revenues—
1980, 1981, and 1982*

	1980	1981	1982
	(millions of dollars)		
Production and distribution costs			
Power marketing	\$ 748.2	\$ 889.6	\$1,001.4
Uranium enrichment.....	1,269.7	1,329.7	1,799.6
Naval petroleum reserve	105.3	194.4	279.3
Total	\$2,123.2	\$2,413.7	\$3,080.3
Revenues			
Power marketing	\$1,127.5	\$1,206.2	\$1,287.4
Uranium enrichment	1,117.0	1,254.0	1,656.0
Naval petroleum reserve	1,945.0	970.0	1,217.0
Total	\$4,189.5	\$3,430.2	\$4,160.4

Each Power Marketing Administration sells electricity produced by the Corps of Engineers, the Department of the Interior's Water and Power Resources Service dams, and the U.S. section of the International Boundary and Water Commission. This power is priced at the lowest rate consistent with the recovery of investment and production costs and sound business practice within the constraints and operating procedures imposed by current regulations and legislative authorities. Statutes provide that preference in the sale of this power be given to public bodies and cooperatives.

Figure 9-1—Electric power marketing areas of the Department of Energy and the Tennessee Valley Authority

The Power Marketing Administrations collect revenues from wholesale customers through rates that are assessed on an essentially uniform basis throughout each regional service area. These revenues help offset annual operation and maintenance costs, repay the capital investment in the power features of various hydro projects, and pay interest on the unrepaid capital invested in power generation facilities. Sales of power from reclamation projects are used to repay irrigation features of the projects that are beyond the irrigators' ability to repay. The revenues from power sales are deposited in the U.S. Treasury.

The general status of the power administrations' revenues, together with their repayments, are summarized in Tables 9-2 and 9-3. Annual appropriations are used to operate four of the five Power Marketing Administrations; Bonneville is self-financed. It is estimated that all five had sales of about 130 billion kilowatt-hours during 1980 and revenues of \$1 billion. These figures compare with 1979's 122 billion kilowatt-hours and \$727 million, respectively. These statistics do not include wheeling revenues.¹ The 1979 figures are grouped in Tables 9-4 and 9-5.

¹Term used to describe transmission line charges by one utility to another.

Table 9-2—Current status of repayment, power systems of the five Power Marketing Administrations

Cumulatively through 1979	(millions of dollars)
Revenues	\$9,106
Expenses paid	
Operation and maintenance	2,921
Purchased power and other	1,309
Interest	2,900
Total	7,130
Remainder applied to amortization	1,976
Cumulative repayable investment	
Power	10,336
Irrigation assistance	1,363
Total	11,699
Less cumulative amortization	1,976
Unamortized investment	\$9,723

Twenty-four interim rate actions and orders were approved during 1979 and 1980; typical examples of these are listed in Table 9-6. The rate actions constituted the largest number ever submitted for approval to the Federal Energy Regulatory Commission in such a short period; the Power Marketing Administrations are now meeting their repayment schedules. In addition, proposed uniform procedures

Table 9-3 — Cumulative repayable investments of the five Power Marketing Administrations

	<i>Cumulative repayable investment through 1979</i>	<i>Repaid</i>
	(millions of dollars)	
Bonneville Power Administration (1938-1979)	\$6,481	\$ 718
Western Area Power Administration (1937-1979)	3,441	987
Southeastern Power Administration (1950-1979)	989	219
Southwestern Power Administration (1944-1979)	670	40
Alaska Power Administration (1955-1979)	118	12
Total	\$11,699	\$1,976

for public participation in power and transmission rate adjustments are in final development and are being coordinated with the Federal Energy Regulatory Commission. These procedures are expected to be released in 1981.

The Power Marketing Administrations cooperate with other elements of DOE on conservation and renewable resource initiatives. An example is the Mod-2 wind generation project. Bonneville, DOE, NASA and its contractor, and local utilities are cooperating on the installation of three 2.5 megawatt wind turbines, which are expected to produce about 30 million kilowatt-hours of electricity each year. When completed, it will be the largest wind generation unit in the world. NASA serves as project manager and will supervise field tests for 2 years. Bonneville's share of the funding is \$1.7 million.

Legislation affecting Bonneville and the Pacific Northwest Region was approved by the House and Senate during the year. Legislation to permit the other four Power Marketing Administrations to invest in electric transmission facilities and other activities was under consideration in both Houses as 1980 drew to a close. Action on the Western Area Power Administration self-financing legislation was approved by the Senate Energy and Natural Resources Committee but was not enacted by the 96th Congress.

Table 9-4 — Primary statistics in 1979 for the Power Marketing Administrations

<i>Power Administration</i>	<i>Transmission lines (miles)</i>	<i>Substations (all voltages)</i>	<i>Powerplants¹ (all types)</i>	<i>Nameplate capacity (megawatts)</i>	<i>Revenues (\$ millions)</i>	<i>Sales (millions of megawatt-hours)</i>
Alaska	90	4	2	77	3	0.3
Bonneville	12,600	347	30	17,927	297	72.0
Southeastern	—	—	21	2,968	59	7.7
Southwestern	1,600	31	21	1,925	62	5.8
Western Area	15,800	213	48	8,050	306	35.0
Total	30,090	595	122	30,947	727	120.8

¹Owned by the Federal Government, operated by the Corps of Engineers and the Water and Power Resources Service; production marketed by the Power Marketing Administrations listed here.

Table 9-5 — Customer breakdown for Power Marketing Administrations

<i>Power Administration</i>	<i>Customers</i>					<i>Total</i>
	<i>Municipals</i>	<i>Cooperatives</i>	<i>Investor-owned</i>	<i>State/county/Federal</i>	<i>Industrial/others</i>	
Alaska	3	1	1	—	—	5
Bonneville	36	54	8	32	31 ¹	161
Southeastern	80	108	8	3	—	199
Southwestern	37	7	7	5	1	57
Western Area	206	41	20	85	112	464
Total	362	211	44	125	144	886

¹Out-of-region and Canadian customers include: 3 California investor-owned, 5 California municipals, 1 state agency, 3 Western Area Power Administration Regions, British Columbia Hydro, and Bountiful, Utah.

Table 9-6 — Selected recent Power Marketing Administration power rate adjustments

Effective Date	Power Marketing Administration	Affected area/project	Incremental amount, dollars	Incremental increase above prior rate, percent
October 1, 1979	Southeastern	Georgia-Alabama	3,600,000	13
November 1, 1979	Western Area	Central Valley	4,400,000	10
December 20, 1979	Bonneville	Systemwide	308,000,000	88
January 1, 1980	Alaska	Eklutna	369,000	23
June 16, 1980	Western Area	Parker-Davis	2,383,000	24
November 1, 1980	Western Area	Colorado River storage	9,700,000	26
January 1, 1981	Southwestern	Transmission system	46,500	10

Uranium Enrichment

The Department of Energy is the sole supplier of uranium enrichment services in the United States. Legislation (Section 161v of the Atomic Energy Act of 1954, as amended) authorizes the Department to enter into contracts to enrich normal (0.711 percent) uranium 235 owned by domestic and foreign utilities. The legislation also requires that charges be made on a nondiscriminatory basis, thereby permitting the Government to recover costs over a reasonable period of time.

One objective is to continue to supply enriched uranium to domestic and foreign utilities well into the next century in an economical, safe, reliable, and environmentally acceptable manner. Another is to instill confidence in the U.S. as a reliable enrichment supplier and at the same time to encourage the responsible use of nuclear power by foreign nations. Also, the U.S. is committed to expanding enrichment capacity through the use of gas centrifuge technology with attendant significant energy savings. At present, most uranium enrichment production is based on the gaseous diffusion process pioneered by the United States during World War II.

Two principal activities have been initiated to ensure that the uranium enrichment program's objectives are met. One is a \$1.5 billion program to increase by 60 percent the efficiency and total capacity of the three U.S. gaseous diffusion plants. Work was more than 90 percent complete by the year's end. Although prolonged strikes (at the Portsmouth Gaseous Diffusion Plant and at one of the major material suppliers for the expansion program) caused some delay, both projects are scheduled to be completed by early 1983. Completion of improvement programs at the Oak Ridge and Paducah sites is still expected by the end of 1981.

The other activity involves the design and construction of a new gas centrifuge enrichment plant capable of providing an additional 2.2 million separative work units (SWU) capacity by 1989 (or about 8 percent of the national capacity), with a further 6.6 million SWU's becoming available sequentially in increments of 1.1 million SWU's per year, as needed, to satisfy demand.

The 1981-1982 program strategy for these activities is based on analysis of alternative supply options, of power and inventory levels, and of Gas Centrifuge Enrichment Plant construction and production schedules. The program calls for operating the three gaseous diffusion plants at reduced power levels to match production levels with projected demand. It also incorporates a 1-year delay in the construction of the gas centrifuge enrichment plant. Both civilian and military demand can be accommodated by this strategy.

Gaseous Diffusion Operations

The three DOE-operated gaseous diffusion plants are at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. These plants were originally built in the 1940's and 1950's to enrich uranium for national defense programs. Today, they provide all of the enrichment services for the domestic nuclear power industry as well as a significant portion of foreign requirements. A small percentage of the plants' capacity is still dedicated to meeting U.S. Government requirements for enriched uranium.

During the past 35 years, the three plants have produced more than 300 million SWUs at an on-stream reliability in excess of 99 percent. Their safety and environmental records have been outstanding. They currently have a capacity of 25.6 million SWUs per year, which will be expanded to 27.3 million SWUs per year by 1983 when ongoing expansion projects are scheduled to be completed.

In 1980, the three gaseous diffusion plants produced 10.8 million SWU's, which represented about 40 percent capacity. This production level required 2,982 megawatt-years of electric power (approximately 1 percent of total domestic electricity use), a decrease of about 1,100 megawatt-years from the previous year. DOE's projected production was adjusted to these power reductions for 1979 through 1981 to match supply with anticipated demand. The DOE enrichment-complex plan for 1981 reflects the reduced-power operational mode. The Department pla

to produce 9.5 million SWUs, based on the purchase of 660 megawatt-years of electricity from its Tennessee Valley Authority, Ohio Valley Electric, and Electric Energy, Inc., power suppliers.

Beyond the capacity expansion programs, work proceeded on construction projects to maintain efficiency and reliable operation and enable the gaseous diffusion plants to comply with current environmental, safety, and health standards. Work was completed on projects to improve the compressed air and nitrogen systems at the Oak Ridge plant, the ventilation system of the Technical Services Building at the Portsmouth plant, and fire protection at the three plants. Existing steam plants at all three locations were converted from oil or gas to burn coal.

Gas Centrifuge Enrichment Plant

Construction of the Gas Centrifuge Enrichment Plant proceeded during the year at Piketon, Ohio, a DOE site adjacent to the Portsmouth Gaseous Diffusion Plant. The plant will add 8.8 million SWUs per year to U.S. uranium enrichment production capacity. The annual electric power consumption of this highly energy-efficient plant is approximately 135 megawatts, or about 5 percent of the power required to produce the same amount of SWUs using the gaseous diffusion process. By the end of 1980, plant design was 55 percent complete, and site preparation and work were under way on the first process building, the recycle/assembly building, and several other support facilities.

The most significant contract award was for the Phase I centrifuge machines, which involved three supply manufacturers and was valued at \$245 million. The contract provides the initial machines for the Gas Centrifuge Enrichment Plant buildings, centrifuge machines for the Centrifuge Plant Demonstration Facility, and qualification testing. The Centrifuge Plant Demonstration Facility is a full, cascade-size enrichment pilot plant scheduled for operation in 1982. Design, construction, and procurement are scheduled to continue at a moderate pace through 1981 with no new major buildings being started.

Naval Petroleum and Oil Shale Reserves

The U.S. Government established three petroleum and three oil shale reserves between 1912 and 1924. Pursuant to Public Law 94-258 (April 5, 1976), Congress directed that the petroleum reserves produce at their maximum efficient rate for a period of 6 years. The law also provides that production can be extended for 3-year increments if the President and Congress so direct. All data collection and policy analysis concerning future development of the oil shale will be carried out under DOE direction.

Naval Petroleum Reserve No. 1

In 1912, President Taft established Naval Petroleum Reserve No. 1 (NPR-1), which encompasses 47,630 acres on the Elk Hills in Kern County, California, about 35 miles west of Bakersfield. In 1944, the Federal Government contracted with the Standard Oil Company of California to undertake the joint exploration, development, and operation of this land.

Toward the end of World War II, oil production from NPR-1 reached 65,000 barrels of oil per day. After a brief period production was reduced to 15,000 barrels of oil per day; and, subsequently, to about 2,500 to 3,000 barrels of oil per day, a level sufficient for testing and field maintenance. Full-scale production was initiated on July 3, 1976, pursuant to Public Law 94-258 and now exceeds 160,000 barrels of oil per day. Most of this oil comes from the Shallow Oil Zone and the Stevens Zone.

Full development of NPR-1 did not begin until August 1973. At the end of 1980, two active drilling rigs were completing two to three wells per month. Both rigs were assigned to the Stevens Zone Development Program.

Approximately 1,300 development wells and 44 exploratory wells are expected to be completed by the end of 1993. As of September 30, 1980, the program was essentially on schedule, having completed 692 development wells and 22 exploratory wells. During 1980, 64 development wells were drilled; no exploratory wells were planned for this period. Average production for 1980 was 159,244 barrels of oil per day. Total revenues derived from the sale of oil and liquid production for 1980 were approximately \$1.5 billion, a figure that includes the windfall profit tax (paid directly to the U.S. Government by the companies purchasing the oil).

Public Law 94-258 required the Government to develop a pipeline by April 5, 1979, to transport 350,000 barrels of oil per day from NPR-1 to shipping or marketing points. Production rates and pipeline capacity from Elk Hills have been reevaluated to between 190,000 and 220,000 barrels of oil per day. It has been determined that sufficient pipeline capacity currently exists to transport virtually all anticipated production from NPR-1. The House and Senate Armed Services Committees have been notified of the reevaluated production rates and anticipated needs for pipeline capacity.

Naval Petroleum Reserve No. 2

By Executive Order dated December 13, 1912, President Taft created Naval Petroleum Reserve No. 2 (NPR-2) at Buena Vista Hills, in Kern County, California, adjacent to Elk Hills. The U.S. Government owns a little more than one-third of the total acreage within NPR-2, which is "checkerboarded" by privately owned lands.

Current production is predominantly stripper,² from which the Government receives a royalty share; its 1980 revenues were approximately \$3.4 million. Most of the reservoirs in NPR-2 have been depleted, and about 9,244 acres of the Government's proven productive acreage is leased out. Accordingly, the Federal role is limited to routine surveillance, production, and fiscal accounting.

Naval Petroleum Reserve No. 3

In 1915, President Wilson established Naval Petroleum Reserve No. 3 (NPR-3), Teapot Dome, in Natrona County, Wyoming. Located about 35 miles north of Casper, NPR-3 consists of 9,481 acres totally owned by the Government.

The development of NPR-3 to its maximum efficient recovery production is near completion. Current plans call for 446 development wells and 16 exploratory wells to be drilled by the end of 1981. During 1980, 54 development wells were drilled; no exploratory wells were planned during this period. Production from NPR-3 averaged 4,393 barrels of oil per day. Total revenues from the sale of oil and de-ethanized gas were approximately \$68.2 million, including the windfall profit tax.

Total production from the Naval Petroleum Reserves is expected to average approximately 179,000 to 187,000 barrels of oil per day during 1981, generating some \$1.8 billion from the sale of crude oil and associated products. Plans call for the drilling of 67 wells on the Naval Petroleum Reserves.

Major construction will continue at NPR-1 during 1981. Activities include the second 100 million-cubic-foot-per-day gas processing plant (low-temperature separation plant No. 2), tank farm electrification, an electrical distribution system, a gas and water injection system, a gas and oil collection system, and liquid products distribution facilities.

Plans call for the installation of a new accounting system at Elk Hills during 1981 and the completion of an independent open-up/shut-in study to assess the necessity for continued production.

Naval Oil Shale Reserves

The Naval Oil Shale Reserves (NOSR's) were established by Presidents Wilson and Coolidge in 1916 and 1924, respectively.

NOSR-1, which encompasses 40,760 acres in Garfield County, Colorado, contains approximately 18 billion barrels of shale oil in place, of which slightly more than 2 billion barrels are estimated to be economically recoverable with current technologies. NOSR-2 encompasses 90,440 acres in eastern Utah, 50 miles south of Vernal and

approximately 120 miles southeast of Salt Lake City, contains an estimated 4 billion barrels of shale in place. There is no current estimate of how much is economically recoverable. NOSR-3, which adjoins NOSR-1 on the east and south, encompasses 14,130 acres in Colorado and contains little oil shale. However, its establishment was considered necessary for working space and spent shale disposal.

The Department of Energy is implementing a predevelopment plan for NOSR's 1 and 3. Emphasis is on the environmental and engineering work needed to evaluate options for development decisions during the coming year. This work includes a study of biological resources (flora and fauna), limited subsurface hydrologic testing on existing holes, collecting meteorological data on NOSR 1, writing a plan for baseline environmental monitoring, and preparing an assessment of environmental, socioeconomic, and cost impacts of the major NOSR development options.

If a decision is made to defer adoption of a specific development approach at this time, predevelopment would continue toward completing the general environmental and engineering work needed to support shale oil development, whether Federal or private.

Part of the overall assessment of technologies supporting the development of NOSR's 1 and 3 was to complete a draft analysis of *in situ* retorting options for NOSR-1. Public meetings were held under the auspices of DOE's Office of Resource Applications before subsequent publication. Similar hearings on the draft program environmental impact statement occurred in November 1980.

This chapter has reviewed a range of services that the Federal Government supplies to the marketplace. Some have evolved for historical reasons, others because national needs were not being met by the private sector.

The operations described involve goods and services from which Government and taxpayer alike seek a fair return for each budget dollar expended. This return reduces overall Federal outlays and avoids market distortions that could result from subsidizing individual elements at the expense of others.

The programs also serve other purposes. For example, the Naval Petroleum Reserves are more than federally operated oil fields; they fill an emergency contingency requirement and are presently employed to exchange oil to fill the Strategic Petroleum Reserve (see Chapter 16). Uranium enrichment (and the associated resource evaluation program) is essential to national defense and also supports domestic and foreign policy objectives. Not only do the Power Marketing Administrations represent separate entities with different histories and needs, but they also form the core of key regional power distribution systems that serve both private and public power companies.

The five Power Marketing Administrations sell hydroelectric power equivalent to approximately 500,000 barrels of oil per day in direct thermal terms. However, if the calcu

² A stripper well is one that produces less than 10 barrels of oil per day.

ion were reversed to show the amount of oil required to generate equivalent electric power, the figure would be more than 1 million barrels of oil per day.

The uranium enrichment program now has 8,300 metric tons of low-assay enriched uranium in stockpile, equivalent to 2.8 billion barrels of oil. Annual production during 1981 should drop to some 0.77 billion barrels of oil equivalent, or nearly 2 million barrels a day, as a result of declining demands for nuclear power. However, by 1987 requirements are expected to rise to the equivalent of 2.1

billion barrels given current firm power contracts. The increase should continue through 1995.

Naval Petroleum Reserves should produce some 190,000 barrels per day next year, gradually reducing this amount to 120,000 barrels by 1987. Production may, however, be considerably higher if exploration and development lead to expanded capacity, if enhanced recovery projects now in the pilot stage prove economically and technically feasible, or if conventional oil and gas are found on the Naval Oil Shale Reserve.

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Chapter 10

Energy Information

Introduction

The complex energy issues facing the Nation cannot be resolved without current, reliable information about the domestic and international energy situation. Such information permits government, industry and business, the academic community, and the general public to make informed decisions on energy issues.

The Energy Information Administration (EIA) was established as both an integral and an independent part of the Department of Energy to respond to national energy information requirements by developing and maintaining an energy information base.

Current information on energy consumption, conservation, supply and demand, domestic production and capacity, reserves, imports, emerging technologies, prices, and the economic structure of the energy industry provides DOE decision-makers with a solid base of information for decisions concerning regulatory duties, policies, and programs. EIA collects and analyzes this information independently of the Department, thus ensuring that DOE and other Government agencies, members of Congress, Administration officials, and the general public receive information that is politically neutral and unbiased.

EIA ensures that the products of the energy information program are meaningful and reasonable and that new data collection instruments have quality built in at the initial design stage. In addition to systematic internal reviews, the quality and integrity of EIA data are further ensured through two independent reviews. A professional audit review team, composed of representatives from six Federal agencies and offices,¹ is legislatively mandated to conduct an ongoing audit of EIA activities. EIA also receives

valuable guidance on a wide range of programmatic and statistical issues from periodic meetings with the American Statistical Association Ad Hoc Committee on Energy Statistics.

In response to its energy data collection surveys, EIA receives and maintains company-specific information. EIA possession of individual respondent information requires appropriate guidelines and security measures governing the distribution of these data. In September 1980, the DOE policy on disclosure of individually identifiable energy information in the possession of EIA was published in the *Federal Register*. This policy, which marks the culmination of 3 years of developmental effort in EIA, sets forth the conditions and terms under which individual respondent information will be shared with other DOE offices, the Congress, the General Accounting Office, other Federal agencies, the states, and the public. It also provides for notification to respondents, on any new or revised EIA data collection form, of the planned uses and possible disclosures of the information they are asked to provide.

While EIA's future plans and budgets are based on existing legislative and program requirements, experience has proven that flexibility is essential to accommodate new legislative requirements and changes in the energy situation. Current efforts are concentrated in six areas: program development, applied analysis, information validation, systems and support, data operations, and information dissemination activities.

¹The team is composed of representatives from the General Accounting Office, the Bureau of the Census, the Counsel of Economic Advisors, the Bureau of Labor Statistics, the Securities and Exchange Commission, and the Federal Trade Commission.

Program Development

EIA is responsible for developing and improving major energy information programs needed for informed analysis of energy events, policies, and programs. Systems are being developed specifically to provide new sources of information on the financial characteristics of the energy industry; oil and gas reserves, resources, and production; and energy consumption. In addition, the Energy Emergency Management Information System provides information that is used for emergency monitoring and decision-making, and the National Energy Information System is being developed to provide the comprehensive framework in which the energy information program operates.

Financial Reporting System

The Financial Reporting System was developed to collect data for the analysis of the financial activities of major energy-producing companies and the competitive structure of the energy industry. This program's first annual report was published in early 1980 and provides detailed, comparable, and consistent information about the financial structure and operation of 26 major energy companies, including information on reported sales and assets and investment patterns. The second report, published in December 1980, provides an extensive analysis of data for the years 1977 and 1978.

In 1981, annual reports for 1979 and 1980 data and a summary report examining trends in the industry from 1974 to 1978 will be published. Studies also have been initiated to determine how the Financial Reporting System might be linked with other systems within EIA and in other Government agencies. By expanding the base of complementary data, such linkages would enable EIA to develop a more complete profile of the energy industry.

Oil and Gas Information System

The Oil and Gas Information System provides a broad range of data needed to understand the Nation's oil and gas resources and the factors affecting their conversion to producible reserves. This system is being implemented on a phased basis, with initial emphasis on developing credible estimates of the Nation's proved reserves of crude oil, natural gas, and natural gas liquids.

Until recently, the Government relied on the American Petroleum Institute and the American Gas Association for estimates of domestic oil and gas reserves. During 1980, EIA collected data from a statistically selected sample of the approximately 16,000 active domestic oil and gas wells and compiled this information into the first two consecutive reports ever produced by the Government on oil and gas proved reserves. The first

report, *U.S. Crude Oil and Natural Gas Reserves, 1977 Annual Report*, was published in February 1980; the 1978 annual report was published in September 1980.

Annual reports for 1979 and 1980 are scheduled to be published in 1981, and, for the first time, will include estimates of proved reserves of natural gas liquids. EIA will continue to explore ways to expand the usefulness of the reserves data base by tying it to corollary oil and gas data programs.

Consumption Data Systems

Timely and complete energy consumption information needed to measure and evaluate residential, commercial, and industrial energy consumption trends is being provided through the Consumption Data System.

Residential Energy Use: Reliable, complete data on energy consumption in the residential sector were published for the first time in 1980. Data collected through the residential energy consumption survey include expenditures for electricity, natural gas, fuel oil, and liquid petroleum gas, as well as information on residential unit characteristics such as size, insulation, major energy-consuming appliances, and fuel storage capacity. Through its household transportation panel, the residential survey also collects information about gasoline consumption in personal vehicles, miles driven, and road performance. The results from this part of the survey will be published in 1981.

Energy Use in Nonresidential Buildings: Comprehensive data on energy use in commercial buildings also are being collected. A national interim survey collects energy consumption data on the age, size, and other characteristics of nonresidential buildings classified by types and amounts of energy used or stored, and by functional end use, such as heating and cooling. This survey will be expanded in future years to provide regional estimates of nonresidential energy consumption.

Industrial Energy Use: To fulfill the legislative requirements of the Powerplant and Industrial Fuel Use Act of 1978, EIA continued to develop the industrial energy consumption information program in order to collect information on the amount of fuel or energy purchased; the amount of waste by-products used as fuel; and the amount of fuel used from nonconventional sources, such as solar, hydro, or wind energy. Basic information on how the energy is used also is being collected.

EIA works with the Bureau of the Census to obtain information about the use of feedstocks in blast furnaces, petroleum refineries, and chemical plants. Whenever possible, EIA will continue to coordinate its data collection with the Census Bureau and other Federal agencies to

prevent costly duplication and to reduce respondent reporting burden.

State Energy Consumption: The Emergency Energy Conservation Act of 1979 requires EIA to monitor the state gasoline conservation targets established by the Department. These targets are voluntary now, but would become mandatory in the event of an energy emergency. In 1980, EIA, in cooperation with the Federal Highway Administration (FHWA), developed a monthly collection form that meets monitoring requirements and supports the highway statistics program of FHWA. In addition, EIA plans to develop a gasohol reporting system, operating parallel to the gasoline monitoring program, that will collect gasohol data required by the Crude Oil Windfall Profit Tax Act. Programs to collect state consumption data for all major fuels, including natural gas, coal, and electricity, also are being developed.

National Energy Information System

The National Energy Information System, created by the Energy Conservation and Production Act of 1976, contains much of the information necessary to carry out the Department's collection, analytic, and forecasting activities. To ensure that the information in the system remains accessible and up-to-date, last year EIA began development of a classification and indexing scheme for energy data, consolidated petroleum data collection systems, tested and evaluated new data systems, and prepared tapes containing economic and energy information for public use. Over the next several years, EIA plans to continue these activities and to review data collection requirements for new energy sources (including synthetic fuels).

Energy Emergency Management Information System

Federal, state, and local government officials require rapid access to energy information prior to and during energy emergencies, such as a gasoline shortage, an oil embargo, or a coal strike. The Energy Emergency Management Information System develops the monitoring and analytic methods and procedures needed to understand the current energy situation and to warn of potential problems.

A pilot system that became operational in March 1980 included a number of components that could be used during an emergency. Among these are an integrated data base providing users with quick access to existing EIA information on oil and gas production, distribution, and consumption; a microfiche file for access and maintenance of relevant reports, contingency plans, regulations, emergency directives, and maps; a file of knowledgeable individuals

to contact for information in an emergency; and a status reporting and monitoring system.

A key component of this system is a two-way electronic message capability that allows state officials to express their views concerning DOE policy and enables DOE expeditiously to obtain and analyze state responses to critical questions during an energy emergency. Communications have been established with appropriate DOE headquarters and regional offices, and 30 state energy offices. Additional state offices are being added to this system.

Applied Analysis

EIA prepares and publishes forecasts and analyses that are used to reduce uncertainty in energy policymaking and planning. Through the use of methodological tools that are credible, documented, and accessible, a broad range of energy and economic data can be analyzed to produce clear explanations and detailed projections. This information is used to assist decision-makers in formulating policy and planning decisions; to assess future energy situations; to determine the effects of energy legislation and regulations; and to assist the public in understanding energy issues.

During 1980, a number of notable analytical publications were released. The quarterly *Short-Term Energy Outlook*, for example, provides projections of energy supply and demand, taking into account factors such as the effects of seasonal changes and the effect of unforeseen events on energy markets.

EIA also completed during the year a comprehensive, congressionally-requested study of Federal energy regulations. Entitled *Energy Programs/Energy Markets*, it compared the effects of current energy policy to a scenario of reduced Government intervention. This analysis can help determine how Government intervention affects the energy industry.

Additional studies completed in 1980 examined such topics as the feasibility of alternative fuel use, reducing utility oil consumption, replacement-cost pricing for energy in the residential and commercial sectors, and the costs and economic effects of filling the Strategic Petroleum Reserve.

In 1981, EIA plans to continue to improve its analytic capability so as to become more responsive to the immediate needs of both Government and non-Government decision-makers. In addition to annual forecast volumes, EIA plans to produce issue and research papers on subjects of continuing interest. These include the effects of Federal subsidies on nuclear power development, uncertainties associated with future coal supplies, issues affecting natural gas supply, and the cumulative impact of Federal regulations on the electric utility sector.

Information Validation

Quality control is exercised in the energy information program by conducting independent reviews of all EIA methods and products. This ensures that the energy information is reliable and that new data collection instruments are designed as effectively as possible. Proposed data systems are reviewed, and recommendations for improvement are incorporated before such systems are approved.

EIA conducted reviews during 1980 to determine data requirements for establishing programs in the areas of natural gas, commercial energy consumption, fuel substitution, and petroleum imports. EIA also conducted studies to ensure that data systems and analysis models conform with sound statistical standards and methodologies. During the year, validation reports were published on four energy data systems—capacity of petroleum refineries, natural gas curtailments, prime suppliers, and joint petroleum reporting. To further improve these systems, EIA is currently implementing recommendations made in these reports.

Over the next few years, validation, documentation, and evaluation activities are to continue. In 1981, validations of data collection systems will continue to concentrate on petroleum information, and evaluations of coal, electric power, and natural gas data systems will get under way.

Systems and Support

EIA manages the computer facility that provides data processing services to DOE's energy data clients; develops new energy data systems and programs and improves existing systems; and reviews energy data collection instruments to ensure that they are reliable and consistent.

In the area of automatic data processing, EIA made significant accomplishments during 1980. Its computer processing capability was increased and current and future data processing requirements of EIA and other DOE users were analyzed to ensure that long-term needs would be adequately accommodated.

EIA provides both technical analysis and computer programming support to the various offices within the Department. DOE offices are provided assistance in designing new information systems and in examining current data systems to identify gaps, eliminate duplicate data, and integrate information systems. Plans are under way to develop a new computer-assisted telephone interviewing system for collecting information more rapidly. Systems are to be developed for collecting information on nonconventional or emerging energy sources such as biomass, wood, and gasohol, and natural gas data necessary to manage curtailments and assess the effects of the Natural Gas Policy Act.

To ensure that data collection instruments are well-designed, concise, understandable, and not overly burdensome to survey respondents, EIA reviews and clears DOE survey forms planned for use by the public. EIA provides technical advice and support to DOE energy data collectors in designing collection instruments and developing sample designs to ensure that data collection efforts conform with sound statistical standards.

Data Operations

To improve the usefulness, credibility, and timeliness of energy information publications, the data operations component collects, processes, interprets, and distributes the basic statistics produced by the Department. More than 600 issues of 40 separate energy data reports are published each year—some focusing on one particular energy source, others covering all major sources. In addition, collection and processing for EIA's 50 operational information systems are handled by data operations.

Over the past year, EIA has made great progress in replacing industry data with Government-collected information in EIA energy data publications. For example, until the spring of 1980 the *Weekly Petroleum Status Report* relied heavily on data supplied by the American Petroleum Institute. Now, all of the domestic petroleum data in the report are collected by the Government.

International exchange of information has been enhanced by the initiation of a program for consistent reporting of U.S. energy supply and consumption statistics to organizations such as the United Nations, the International Energy Agency, the North Atlantic Treaty Organization, and the Economic Commission for Europe. Information on energy production in various foreign countries is published annually by EIA.

EIA has focused on improving the usefulness of publications by both consolidating collection and publication procedures, and by broadening the scope of publications. For example, *Electric Power Monthly*, a new comprehensive periodical of electric power statistical data, consolidates information previously published in five publications. In 1981, coal and petroleum data, like electric power data, will be consolidated, and EIA will begin to evaluate data on nonconventional energy sources.

Information Dissemination Services

As part of its mandate to make statistical energy data readily available to the Nation, EIA carries out a comprehensive program to market and distribute EIA products and services, and to develop new programs and materials that are easily understood by individual consumers.

EIA has made significant progress in expanding the outreach activities of its energy information program.

brochures describing its activities and consumer-oriented publications were developed during the year to make important energy data more readily accessible. For example, EIA prepared and published a series of fact sheets on energy topics of general interest to consumers. Topics included projected prices and availability of gasoline, heating oil, and natural gas; energy tax incentives; and residential energy use and cost. These fact sheets and other energy information are being distributed to consumers

through state and regional energy offices. To provide public access to standard bibliographic information on all EIA publications, and descriptions of the types of data in the publications, a computerized data base, the Federal Energy Data Index, has been developed.

EIA also houses the National Energy Information Center, which annually responds to over 30,000 inquiries on energy-related topics from persons both inside and outside Government.

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Chapter 11

Economic Regulation

Introduction

The Economic Regulatory Administration (ERA) is responsible for developing and implementing a number of departmental programs designed to ensure adequate and reliable supplies of energy to meet the needs of this country. This chapter is devoted primarily to the programs and activities of ERA. At the end, it briefly covers the Office of Hearings and Appeals, which is responsible for handling exceptions to DOE regulations and for appealing orders.

ERA's responsibilities include requiring the use of more abundant fuels, such as coal, instead of oil and natural gas in powerplants and major industrial facilities; ensuring equitable distribution and pricing of petroleum and petroleum products; controlling exports and imports of oil, natural gas, and electricity to protect national interests; working with state authorities to encourage greater conservation, fuel efficiency, and equitable pricing by local utilities; and enforcing existing laws. These responsibilities were carried out in 1980 with increased emphasis on guiding, rather than regulating, the various energy industries.

During 1980, ERA reduced the regulatory burden on industries by simplifying regulations necessary to carry out the requirements of law and by eliminating unnecessary rules. In this regard, ERA continued to implement the

President's program of phased decontrol of crude oil, which resulted in decontrol of more than 60 percent of domestically produced crude oil during 1980.

The manpower for ERA for the years 1980, 1981, and 1982 is summarized in Table 11-1.

Table 11-1—Manpower applied to economic regulatory programs—1980, 1981, and 1982

<i>Program</i>	<i>1980</i>	<i>1981</i>	<i>1982</i>
Fuels conversion	232	250	274
Petroleum operations	289	267	123
Utility programs and regulatory intervention	120	107	107
Compliance	1,363	1,301	718
Emergency preparedness	56	51	31
Program administration	51	51	45
Total	2,111	2,027	1,298

Fuels Conversion

Pursuant to the Powerplant and Industrial Fuel Use Act (FUA), ERA implemented a coal conversion program resulting in the issuance of proposed prohibition orders or commitments to voluntary conversions of 68 powerplants and major fuel-burning installations. ERA has emphasized

and encouraged voluntary conversions whenever possible, as they are administratively more efficient and generally occur more rapidly.

These actions have generated potential oil savings of approximately 259,000 barrels per day. Of these potential savings, 257,000 barrels per day are in the electric utility sector, which currently consumes approximately 1.4 million barrels per day of oil and 1.6 million barrels per day (oil equivalent) of natural gas.

FUA authorizes ERA to issue orders prohibiting oil or natural gas use in existing electric powerplants and industrial and Federal facilities capable of using coal or an alternative fuel. Prior to final issuance of prohibition orders, ERA must find that the affected facilities have the technical capability to use coal or another alternative fuel as a primary energy source without substantial physical modification or substantial reduction in the rated capacity of the unit, and that the use of coal or an alternative fuel is financially feasible. Conversions ordered under FUA may require other Federal, state, and local approvals and the installation of the required pollution control and technical equipment. The preparation of environmental impact analyses are also necessary to comply with the National Environmental Policy Act.

All Federal facilities are subject to FUA prohibitions. Two executive orders issued in December 1979 and June 1980 emphasized the implementation of FUA by the Federal sector. Federal agencies have been directed to consider the implementation of FUA in their contract procurement and financial assistance programs and to report annually to DOE regarding conversion of their facilities to coal or another alternative fuel.

Ten Federal facilities are expected to convert to coal or an alternative fuel as a result of proposed prohibition orders and voluntary commitments. A data gathering effort to determine other potential Federal facility conversion candidates was initiated during 1980.

DOE granted 1,003 temporary public interest exemptions from FUA prohibitions to enable existing electric powerplants to use natural gas to displace approximately 350,000 barrels of oil per day. FUA prohibits electric powerplants from using natural gas as a primary energy source unless such powerplants used natural gas as a primary energy source in 1977. FUA also prohibits the use of natural gas in greater proportion than the average yearly proportion for the years 1974 through 1976. Because surplus natural gas is currently available, ERA issued a special rule to permit the use of natural gas to displace oil that would otherwise be imported.

In addition to the public interest exemptions, temporary exemptions may be granted because of a lack of an alternative fuel supply, site limitations, future use of synthetic fuels, and environmental requirements. Temporary exemptions may be granted for up to 5 years, and some

may be extended for an additional 5-year period.

FUA prohibits the use of oil and natural gas in new industrial facilities and electric powerplants unless DOE grants an exemption. Exemption petitions for 63 units are now being processed by ERA. As of December 31, 1980, ERA had granted 33 exemptions—21 to industrial facilities and 12 to utility powerplants.

Permanent exemptions are available for a variety of situations. Permanent exemptions available to major fuel-burning institutions include exemptions based on product or process requirements and exemptions that would be necessary to meet scheduled equipment outages. Permanent exemptions available to electric powerplants include exemptions necessary to maintain reliability of service and exemptions pertaining to peak load and intermediate load powerplants.

During 1980, ERA simplified regulatory processes under FUA and reduced the reporting burdens in three significant respects:

1. Self-certification procedures are now applicable in most exemption cases.
2. Reporting requirements for certain exemptions were simplified.
3. Regulations were modified to limit the number of firms needing an exemption to burn certain mixtures of oil and alternative fuels.

Utility Systems

ERA utility programs are designed to promote rate reform, encourage conservation in the production and use of electricity, and seek to ensure an adequate, reliable, and economic bulk power supply.

In 1980, ERA issued final rules awarding Federal grants to state regulatory agencies and publicly owned electric utilities for rate design initiatives, and awarded \$16 million for these grants. ERA also revised the form used by the states to report annually on their utility regulation activities. These reports provided a basis for the first annual assessment of state utility regulation. ERA also issued guidelines for state regulatory agencies on various rate reform and regulatory standards included in the Public Utility Regulatory Policies Act (PURPA).

The Natural Gas Rate Design Study required under PURPA was completed and the report was submitted to Congress in May 1980. Grants were made in 1980 to 12 states to help state consumer offices assess the impact of utility rate changes on consumers and to assist consumers in presenting their positions before state utility regulatory commissions.

In 1980, DOE issued several major reports and studies concerning the adequacy and reliability of the Nation's electric supply system. These included: *The National Power Grid Study*, *The Study of the Problems of Small*

ilities in Complying with the Fuel Use Act, A Ten-Year Electric Power Supply Adequacy Report, A Report on the Potential for Increased Electricity Exchange Between the United States and Mexico.

ERA also encouraged actions to permit more effective utilization of scarce fuels by electric utilities, including energy brokering, powerplant productivity enhancement, and fuel displacement electricity transfers.

ERA is authorized to intervene or otherwise participate in state and Federal regulatory proceedings to further the purposes of national energy policy. Interventions involve the presentation of testimony and evidence in regulatory proceedings at both the state and Federal levels. During 1980 these interventions addressed:

1. Reform of electric and natural gas policies and rate structures
2. Implementation of utility conservation, load management, power pooling, wheeling, and inter-connection projects
3. Establishment of oil, gas, coal, and other energy price and transportation policies
4. Recognition of new and alternative energy supplies, including solar, geothermal, wind, biomass, and other renewable energy resources

Federal and state proceedings are monitored to identify additional intervention opportunities in which DOE's participation would contribute to achieving national energy policy objectives.

Petroleum Operations

During 1980, ERA continued its programs to phase out controls on crude oil. As necessary, ERA will continue to operate programs for crude oil and petroleum products under the Emergency Petroleum Allocation Act until the act expires on September 30, 1981. In addition, ERA provided assistance to the states and to industry in managing temporary supply disruptions resulting from phased decontrol.

ERA's activities concerning crude oil and petroleum products, including aviation fuels, middle distillate, motor gasoline, residual oil, natural gas liquids and propane, are discussed in the following sections.

Crude Oil

More than 60 percent of all domestic crude oil is uncontrolled as of December 1980, with the balance to be released during 1981. During 1980, ERA continued the implementation of programs to encourage increased exploration and production.

Enhanced crude oil recovery program: This program was implemented to increase domestic production from wells utilizing unconventional recovery techniques. The pro-

gram provides economic incentives for crude oil production by providing a portion of the initial costs of new or expanded tertiary recovery projects through release of additional production from price controls. More than 230 tertiary recovery projects, representing a tenfold increase in the initiation of tertiary projects, have been approved. A significant volume of incremental oil production is potentially available from the tertiary techniques being applied under the program. These techniques have already resulted in a 2700-percent increase in crude oil produced from tertiary wells.

Entitlements program: This program is designed to distribute the benefits of price-controlled crude oil among all refiners. This program facilitates crude oil purchases for the Strategic Petroleum Reserve by reducing the reserve's crude oil costs. Moreover, the program grants entitlement benefits to eligible producers to encourage the development of alternative fuels.

Crude oil allocation program: This program provides a means of allocating crude oil on a semi-annual basis to small refiners experiencing crude oil shortages. The program accommodates emergency allocations of crude oil when required.

Aviation Fuels

Aviation gasoline and kerosene-base jet fuel were deregulated in February 1979. Supplies of kerosene-base fuels are generally adequate, but aviation gas supplies remain tight. During the year, ERA assisted aviation consumers to secure supplies of aviation fuels, including supplies for new airlines and airlines with new air routes.

Middle Distillates

Middle distillates have been decontrolled since 1976. Three major studies examining refiners' costs and revenues associated with home heating oil found that efforts to increase distillate supplies have moderated pressures to raise prices, while low-income energy assistance has reduced the burden on families least able to afford these fuels. DOE, in conjunction with the Fuel Oil Marketing Advisory Committee, issued a report on low-income energy assistance that played a major role in the development of the current \$1.6 billion low-income energy assistance program.

Motor Gasoline

Motor gasoline remains under price and allocation controls. Changing market strategies by the industry are resulting in the closing of small-volume, full-service stations and a shift to high-volume, self-service gasoline retail outlets. In 1980, ERA processed more than 40,000 requests

for allocations of gasoline, including requests from new service stations and end-users, and other requests for ERA assistance.

ERA initiated actions to improve the case processing capabilities and information systems of the DOE regional offices through the use of modern management techniques and equipment and by redesigning forms used to obtain the information necessary to act on requests for assignments of motor gasoline.

Motor gasoline stocks have been at a high level throughout the year reflecting decreased demand. High gasoline prices have been a primary force in reducing demand and making gasoline readily available in the spot market.

Residual Oil

Prices of residual fuel oil, which is decontrolled, rose sharply as crude oil prices increased. The entitlements program was amended to extend the benefits for purchases of imported residual fuel oil to the east coast and Michigan.

Natural Gas Liquids and Propane

Propane and the propane content of natural gas liquids remain under price and allocation controls. Butane and natural gasoline were deregulated as of January 1, 1980, and propane deregulation is under consideration.

Synthetic Natural Gas Feedstocks

Effective December 15, 1980, ERA exempted naphtha used as a synthetic natural gas feedstock from allocation regulations and placed allocations to existing synthetic natural gas plants that use propane as feedstock at their historical level of usage. The result of these allocation revisions is to remove synthetic natural gas plants from all remaining allocation controls.

Compliance Activities

During the year, DOE compliance programs resulted in criminal convictions of 17 firms or individuals, referrals to the Department of Justice of 18 cases involving 45 firms alleging willful violations, and identification of \$10.7 billion in civil overcharges.

Two ERA offices are responsible for DOE compliance efforts: the Office of Special Counsel for compliance, which is responsible for enforcing price and allocation regulations of the Nation's 35 largest refiners, and the Office of Enforcement, which is responsible for such regulations with respect to all other firms making up the petroleum industry.

Office of Special Counsel

The Office of Special Counsel was created to audit the Nation's 35 largest refiners to determine their compliance with DOE's pricing and allocation regulations. These 35 refiners control 90 percent of the Nation's refining capacity and a significant portion of crude oil production and product marketing activities.

During 1980, the Special Counsel issued approximately 200 compliance documents identifying \$4.6 billion in overcharges, including the largest allegation of pricing violations ever filed by DOE which charged seven major refiners with multiple pricing violations totaling \$1.7 billion. The Special Counsel also completed audits of the 35 largest refiners for the period 1973 through 1976.

The Special Counsel reached comprehensive settlement agreements with five major refiners (Amoco, Phillips, Sun, Cities Service, and Getty) settling all disputed issues. These settlements resulted in \$64.4 million in direct refunds to customers, \$20 million in price rollbacks, \$575 million in "banked costs" reductions, \$510 million in investment commitments, and \$96 million in restitution payments.

The Iranian Revolution and the subsequent shutoff of Iranian oil, as well as U.S. gasoline supply problems in 1979, prompted the Special Counsel to investigate and audit industry inventory practices of the 18 largest refiners. During 1980, the Special Counsel completed comprehensive reports of gasoline price and allocation practices for this critical period.

Office of Enforcement

The Office of Enforcement is responsible for auditing the thousands of smaller firms engaged in production, refining, and reselling of petroleum and petroleum products to ensure compliance with Federal pricing and allocation regulations. During 1980, the Office of Enforcement identified more than \$1.1 billion in possible overcharges and issued 415 documents citing violations for more than \$793 million. Of those documents, 151 were consent orders for final settlements reached with firms involving pricing violations totaling \$135 million. One consent order was for \$24.7 million—the largest single consent order in the history of the Office of Enforcement.

Special attention was given to crude oil reseller audits in 1980, with emphasis on detecting and prosecuting crude oil resellers who failed to certify properly their crude oil transactions. As a result, 35 firms were cited for nearly \$240 million in violations. A \$10 million consent order was signed by a crude oil reseller for allegedly buying and reselling crude oil without certification and allegedly charging illegal prices for its crude oil. A Notice of Probable Violation was also issued to a crude oil reseller for alleged

iscertification of stripper oil. During 1980, the Crude Oil Reseller's Self Reporting System was implemented and action was taken to enforce the system's filing requirements by issuing more than 100 notices to firms that failed to file the required reports.

The Office of Enforcement intensified its investigation of gasoline price selling violations and conducted nearly 21,000 audits of retail gasoline dealers during 1980. Nearly 4,900 of these firms were found in violation of the Department's retail gasoline pricing regulations. These retail firms paid more than \$1.1 million in civil penalties and agreed to implement price rollbacks amounting to more than \$3.8 million. Many of these audits were conducted as a result of complaints received on the Department's hotline, which was established to allow consumers to register complaints on gasoline prices and supply.

During the year, the Special Investigations Division made 18 referrals of possible willful violations to the Department of Justice. These referrals requested the Department of Justice to initiate criminal investigations of firms and individuals that may have willfully violated DOE regulations and related Federal statutes. Such alleged violations include the willful miscertification of crude oil, fraud on the entitlements program, willful misdirection of allocated products, and willful pricing violations. In addition, there were 22 criminal convictions and 13 grand jury indictments, and court orders were issued involving more than \$3 million in civil and criminal fines. These actions resulted from earlier investigations conducted by the Department of Energy.

Energy Contingency Planning

ERA's Office of Energy Contingency Planning was established in April 1980 to provide Department-wide coordination and centralized focus for the development of energy contingency plans.

The initial task of Energy Contingency Planning is to prepare a prototype contingency response plan for a hypothetical oil embargo. While it is not possible to

prepare detailed contingency plans for every conceivable eventuality, the prototype plan will serve as a base from which adjustments can be made quickly to fit an actual situation.

In addition to contingency planning activities at the Federal level, Energy Contingency Planning has encouraged increased planning efforts by private industry. Representatives of trade associations for energy producing and consuming industrial sectors have been asked to identify barriers which may jeopardize national emergency preparedness. A full range of proposed legislative and management initiatives has been solicited from the private sector.

Energy Contingency Planning is discussed at length in Chapter 16.

Office of Hearings and Appeals

The Office of Hearings and Appeals is the focus of DOE's adjudicatory and appellate activities. It carries out a broad range of activities related to all DOE programs and regulations. Hearings and Appeals is responsible for analyzing and deciding upon applications for exception from any DOE regulatory program. In addition, orders of the Department (other than proceedings involving the Federal Energy Regulatory Commission) are generally appealable to Hearings and Appeals.

Of particular significance was the large number of submissions relating to the pricing and allocation of motor gasoline. In an effort to respond expeditiously to this large caseload, Hearings and Appeals authorized a number of class exception proceedings. Also, during the early part of 1980, a number of petitions seeking exceptions from the building temperature regulations were received and acted upon.

All hearings are open to the public. When a matter is particularly urgent, a decision is often reached on the same day. Summaries of final decisions are published in the *Federal Register*. During 1980, more than 23,323 determinations were issued by the Office of Hearings and Appeals.

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Chapter 12

General Sciences

Introduction

The Department of Energy supports three general science programs—High Energy Physics, Nuclear Physics, and Life Sciences and Nuclear Medicine Applications. Although they do not support directly the Department's efforts to develop energy technologies, the new knowledge gained from this research affects such diverse and nationally important areas as energy, the environment, medicine, and technology development.

High Energy and Nuclear Physics

The Department's High Energy and Nuclear Physics programs constitute nearly 90 percent of all such research conducted in the United States. These programs, which are carried out as a national trust, differ from other departmental basic research efforts in that the research itself and the knowledge it produces are the goals. Both programs seek an understanding of the ultimate structure and constituents of all matter and energy and the four basic forces of nature governing their behavior. Gravity and electromagnetism are the two more familiar forces. The other two are the strong nuclear force, which holds the nucleus together and plays a major role as a source of solar, fusion, and fission energy; and the weak nuclear force, which controls the radioactive decay processes of elementary particles and nuclei.

High Energy Physics focuses on the elementary particles themselves—their creation, their transformations, and the forces and other relationships among them.

Nuclear Physics concentrates on the interactions, structure, and other fundamental characteristics of the atomic nucleus, which can be characterized as a cluster of elementary particles. Though differing in scope, these programs have several similarities. These include the historical development of their research programs, the nature of the facilities required to do the work, the potential applications in other fields, and the international aspects of the research.

Historically, scientists have probed ever more deeply into the structure of matter in an attempt to discover its fundamental nature. During this century, the frontiers of exploration have included the atom, its nucleus, and the subnuclear world that includes protons, neutrons, and many other less familiar elementary particles. In the last few years, strong evidence has accumulated attesting to the existence of a previously unknown, more basic level of structure of matter and energy. All of the well-known subnuclear particles, such as protons and neutrons, are now believed to consist of a small set of quarks—which can be described as the basic building blocks of matter. Every step into the structure of matter—atomic, nuclear, and subnuclear—reveals a host of new and unexpected phenomena, particles, and forces.

Experiments in high energy and nuclear physics depend on large particle accelerators to produce the energetic particles required to study atomic nuclei and elementary particles. The smaller the particle to be studied and the higher the energies holding its component parts together, the larger and more powerful are the accelerators, detectors, and other equipment required to do the research.

Although the cost of research is high and it often takes years to comprehend the results, fascinating possibilities are created for increasing knowledge of the fundamental nature of matter and energy and for applying technology developments gained from the research. Many developments are applied to such diverse fields as cancer therapy and the testing of materials for use in fusion reactors.

During 1980, nearly all of the high energy and nuclear physics research was carried out under contracts either with universities or with university laboratories. The exceptions are the Oak Ridge National Laboratory, operated by Union Carbide, and a few small contracts with industrial firms. About 75 universities, 8 DOE laboratories, and other institutions participated in the Department's High Energy Physics program, while 55 universities and 9 laboratories participated in the Nuclear Physics program.

International Cooperation

Internationally, the United States enjoys a position of world prominence in most high energy and nuclear physics research areas. Other countries are now conducting vigorous programs, with major research occurring in Western Europe, the Soviet Union, and Japan; and a new high-priority program is under way in the People's Republic of China.

International cooperation in high energy and nuclear physics research results in frequent exchanges of visitors, internationally sponsored conferences, and collaborative research using facilities in the United States and in other countries. Although some of the transfer of research data is undertaken in a formal manner, most of the cooperative work with Western Europe is done on an informal laboratory-to-laboratory basis. On the other hand, collaboration between the United States and the Soviet Union is carried out under U.S.-Soviet agreements on the peaceful uses of atomic energy. A U.S.-U.S.S.R. Joint Coordinating Committee on Research in the Fundamental Properties of Matter monitors these activities and agrees annually on the cooperative program for the following year.

A joint committee also coordinates the Cooperative Program in High Energy Physics undertaken by the United States and the People's Republic of China. Work takes place under a series of agreements that were signed in January 1979. During the first years of the cooperative program, the United States provided assistance to the People's Republic of China in the design and development of a 50-billion (Giga) electron volt synchrotron being built on a full-cost recovery basis near Beijing. A similar agreement in nuclear physics research is being discussed with the Chinese Government.

As a result of formal agreements with the Japanese Government that were signed in 1979, cooperative high

energy physics experiments are under way at a number of laboratories, including Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley Laboratory, and Stanford Linear Accelerator Center. Recent plans include new joint accelerator research and development programs to be implemented in 1981. Cooperative work in nuclear physics also is being discussed.

High Energy Physics

In recent years, the High Energy Physics program has made great technological and conceptual progress toward understanding the ultimate structure of matter and energy. The primary method for studying the four fundamental forces of nature and the characteristics and structure of matter is to investigate the interactions of very high energy particle beams with other particles of matter. The particles in these beams are generated by high energy particle accelerators and are made to collide with other particles in fixed targets or in other beams. Information is gained by studying the results of these collisions and the properties of the new particles created in them. Advanced technology is indispensable for providing the high energy accelerators, colliding beam systems, sophisticated particle detectors, and data analysis capabilities necessary for the studies. Moreover, this type of research challenges scientists to provide increasingly advanced capabilities, which in turn stimulate researchers to attempt previously impossible experiments.

In addition to the benefits for high energy physics research, the vigorous development of advanced technology has produced numerous and often spectacular spinoffs. The parabolic solar collector, superconducting magnets, and advanced applications of computers for data collection and analysis are a few of the bonuses of these advancements. In addition, the full range of accelerator technology has been used in the development of ion beam fusion, accelerators for medical diagnosis and treatment, and accelerators for use as pulsed neutron and synchrotron light sources for materials sciences research.

The High Energy Physics program operates under a long-range plan established by DOE and the Office of Management and Budget. The plan sets the basic structure and funding level for the program and is designed to maintain a position of world leadership for the United States in the field. The plan calls for effective operation of three U.S. accelerator centers and the development of special new research capabilities at each laboratory center.

University research groups throughout the country use the accelerator and experimental facilities at each of the three national centers: Brookhaven National Laboratory, Fermi National Accelerator Laboratory, and the Stanford Linear Accelerator Center. The supporting

technology research and development programs, which provide the scientific and technological base necessary for continued development of the accelerators and other facilities, are centered primarily at the three national facilities and at Argonne National Laboratory and Lawrence Berkeley Laboratory.

The new capabilities called for in the long-range plan focus on the areas of higher energy electron-positron colliding beams at the Stanford Linear Accelerator Center, high energy proton-proton colliding beams at Brookhaven, and higher energy proton fixed target experiments and high energy proton-antiproton colliding beams at Fermilab. Accelerator construction projects under way include a three-phase upgrade of Fermilab comprised of the Energy Saver, Tevatron-I, and Tevatron-II. Upon completion of these projects, Fermilab's accelerator and experimental facilities will be able to produce secondary particle beams at higher energies and intensities than anywhere else in the world. The Intersecting Storage Accelerator (Isabelle) facility is being constructed at Brookhaven. The facility represents a giant step forward in research capability, from an energy range of 60-Giga electron volts to 800-Giga electron volts. Further information on these projects can be found on pages 86-99 of the *Project Summaries* report (*Secretary's Annual Report to Congress*, Volume III, January 1981).

Project Summaries report (*Secretary's Annual Report to Congress*, Volume III, January 1981).

Experimental research efforts during 1981 and 1982 are expected to concentrate on the search for new forms of matter associated with heavy quarks, properties of the strong force as compared to the new theory of strong forces, and properties of the weak force as exhibited in the theory that has been successful in providing a unified description of the weak and electromagnetic interaction. The authors of this unification were honored by the Nobel Prize in Physics for 1979. Theoretical research is expected to concentrate on further development of the new theory of strong interactions and the attempts to bring the strong interaction force into a unified theory, which would include the weak and electromagnetic force.

Research accomplishments in high energy physics can best be appreciated by viewing them in the broad framework of the state of the field and by recognizing the time scales involved. It takes several years to mount an experiment and, in many cases, it can take another several years to analyze the research results. Figure 12-1 illustrates some scientific implications of recent accomplishments in the High Energy Physics program.

Figure 12-1—Scientific implications of recent accomplishments in the High Energy Physics program

The 1980 Nobel Prize in Physics was awarded to Val L. Fitch, Professor of Physics at Princeton University and James W. Cronin, Professor of Physics at the University of Chicago for their outstanding experiment on K-meson decay. Completed at the Alternating Gradient Synchrotron of the Brookhaven National Laboratory in 1964, their work directly contradicted then-current ideas of the symmetries of nature. Implications of the discovery relate to the fundamental forces of nature and contribute to an explanation of the fact that the universe is dominated by matter with only a small fraction of antimatter present.

Outstanding progress in theoretical understanding has resulted in the last few years from the construction of a unified theory of weak and electromagnetic forces and a similarly constructed theory of the strong interaction force called quantum chromodynamics. These new theories have predicted several key features of high energy processes, some of which have been confirmed experimentally. Work is progressing rapidly on the next stage, that of unification of the weak, electromagnetic, and strong forces. A recent theory of the unification of these three fundamental forces makes an astounding prediction—that the proton is not stable as has been thought, but rather may decay with a finite lifetime. The predicted lifetime is so long that the decay may be only barely detectable by using an exceedingly large number of protons and looking for a few decays over several years. Two large experiments began during the year aimed at identifying this proton decay.

Fundamental measurements of neutrino scattering from electrons are continuing in experiments at the Brookhaven National Laboratory. These difficult measurements of a very rare process, in which chargeless and possibly massless neutrinos are observed to bounce off electrons, provide important information to test predictions of the unified theory of weak and electromagnetic forces.

Calculations using current force theories have shown that many observed particle interactions can be understood if the proton and neutron are composed of even more basic entities called quarks and gluons. Gluons are thought to be the carriers of the strong force somewhat analogous to the photon for the electromagnetic force. United States teams have played a significant role in recent research efforts in Europe. During one experiment in particular, at the PETRA Facility in Germany, properties of gluons were measured using high energy electron-positron colliding beams. At the European Organization for Nuclear Research in Geneva, the ISR Facility's proton-proton colliding beams produced energetic single photons thought to represent a measure of the gluon content in the proton.

Research performed under the High Energy Physics program resulted in several other recent outstanding achievements related to the structure and constituents of

matter. For example, at the Stanford Linear Accelerator Center, the SPEAR storage ring produced electron-positron collisions in which an extremely rare particle called the "charmed eta" was created. This particle was found with the mass and other properties that agree with theoretical predictions. There remains a rich area of work at SPEAR that focuses on the systematic study of an entirely new kind of matter characterized by the property called "charm" and its associated c-quark.

At Fermilab, recent experiments have directly measured charmed particle lifetimes using nuclear emulsions together with downstream electronic detectors. These lifetimes are in a range that was previously unmeasured because of the short times involved. Also at Fermilab, the pion's internal structure was measured in an ingenious way, by observing muon pairs produced in pion-nucleon collisions at very high energies.

The discovery of the upsilon particle at Fermilab in 1977 was the first indication of another completely new type of matter which is thought to contain a new and heavier quark, the b-quark. The lightest quarks (u-quarks and d-quarks) are the constituents of normal matter, such as protons and neutrons found in atomic nuclei.

A worldwide effort has been initiated to discover other related new forms of matter. To date, evidence has been discovered of five kinds of quarks, which are associated with the fundamental strong force. At the CESR Facility (a positron-electron collider facility at Cornell University, funded by the National Science Foundation), the observation of heavier members of the upsilon family of particles is continuing at a rapid pace, and their detailed properties are being explored.

In addition to these physics research achievements, progress has been made on new experimental facilities required for the continued advancement of high energy physics research. At the Stanford Linear Accelerator Center, the construction phase was completed on the Positron-Electron Project storage ring. This phase was finished on time and at cost, and the storage ring, which is used to collide electron and positron beams, achieved both circulating and colliding beams.

At Fermilab, the Energy Saver project is progressing rapidly with fabrication of its very advanced technology facility. High field superconducting magnet production is proceeding well, and stringent design criteria are being met. The mammoth Central Helium Liquefier plant used to cool the superconducting magnets also achieved two-thirds capacity and, when fully operational, will be able to liquefy more helium than all the other plants in the world combined.

At Brookhaven National Laboratory, the Isabelle proton-proton collider project has achieved good progress on the associated accelerator tunnel and other construction

als, and work is proceeding on the development of specially designed superconducting magnets.

Particle detectors at Stanford Linear Accelerator Center, Fermilab, and Brookhaven are some of the supreme examples of technical achievements in the field. For example, positron-electron colliding beam experiments are performed at Stanford on the Crystal Ball detector which lights up with protons; the DELCO, MAC, and MARK-II, which crackle with detection of charged particles; and the High Resolution Spectrometer with its massive superconducting magnet for precision measurements. Figure 12-2 is a photograph of the MARK-II detector. The Lawrence Berkeley Laboratory-designed Time Projection Chamber, a detector so advanced it will be in a class by itself for many years, is being developed and should be installed during the next year.

The universities are conducting most of the accelerator experiments and thus producing most of the fruits of research from the Nation's accelerator laboratories. They also are proceeding on some non-accelerator tests. A typical experiment takes place in deep mines to find decays of protons, which are extremely rare events that have been predicted by theories unifying the description of strong, weak, and electromagnetic forces. Other "neutrino oscillation" experiments are set up near nuclear reactors to be sensitive to tiny neutrino mass effects.

Nuclear Physics

Currently, much information is available about the static properties of stable nuclei found in nature. The frontiers of nuclear physics have now progressed to the investigation of the internal dynamics of nuclei and the investigation of the response of nuclear matter to extreme conditions.

The collision of an accelerated heavy nucleus with a target nucleus creates extremes of density, pressure, and temperature in nuclear matter. By observing the most violent collisions, one can determine the response of nuclear matter to rapid compression and heating, study the mechanisms that transfer matter and energy during a collision, and seek evidence of the existence of new high density states of nuclear matter or possibly even quark matter. By investigating nuclei under extreme conditions and with new probes such as pi- and K-mesons (mesons are an important class of subnuclear particle), current theoretical understanding of the structure, interactions, and properties of nuclei is extended and connections between these and the fundamental forces of nature are tested and better understood.

The work of the Nuclear Physics program demands intense, high-quality beams of accelerated electrons, protons, and heavy ions over a wide but precisely controlled

range of energies. These primary beams are used both directly and to produce essential secondary beams of neutrinos, muons, photons, neutrons, pi-mesons, and K-mesons. As in the High Energy Physics program, this research program has spurred accelerator technology and instrumentation that benefit other areas of research. For example, a new high-intensity linear accelerator was developed under the program. In addition to nuclear physics research, this concept is being applied to the design of an accelerator to test materials for use in fusion reactors.

Illustrative of the more immediate applications of accelerator technology development is the ongoing research on a promising method of cancer therapy. Undertaken in cooperation with the National Cancer Institute, this research uses beams of elementary particles produced by a proton accelerator whose main function is the production of particles for research on the interactions of atomic nuclei.

Nuclear Physics program studies are grouped under medium energy nuclear physics, heavy ion nuclear physics, and nuclear theory. Medium energy nuclear physics focuses on experiments at the electron and proton accelerator facilities that produce pi-mesons.

The Anderson Meson Physics Facility, operated by the Los Alamos National Scientific Laboratory, and the Bates Linear Accelerator Facility, operated by the Massachusetts Institute of Technology, are, respectively, the leading medium energy proton and electron facilities in the world. The former accelerates protons to an energy of 800 million electron volts (MeV). In addition to the pi-mesons used in nuclear interaction studies, it makes secondary beams of nuclear probes including muons, neutrons, and neutrinos. These uniquely intense secondary beams are used for studying nuclear properties and the fundamental forces of nature as well as for researching human cancer therapy, materials research, and weapons applications. Electron beams are accelerated at Bates to reveal the finest detail of nuclear structure. This is possible because the scattering interaction of an electron with nuclei is governed by the well-understood electromagnetic force. Hence, its effects on nuclear systems can be analyzed with great precision.

Powerful heavy ion accelerators, such as those in operation at the Lawrence Berkeley Laboratory, and several other Department of Energy laboratories and universities, allow acceleration of the complex nuclei (consisting of up to a hundred or more neutrons and protons) that are the subject of heavy ion nuclear physics study. One such heavy ion accelerator is the electrostatic accelerator at the University of Washington (Figure 12-3). Because of the ability of heavy ion projectiles to transfer large amounts of energy, mass, and spin to target nuclei, heavy

Figure 12-2—Mark-II detector at the positron electron project located at the Stanford Linear Accelerator Center

Figure 12-3—Electrostatic Accelerator, University of Washington

ion nuclear physics offers new opportunities for studying nuclei under extremes of density, pressure, and temperature. Heavy ion beams also are used to create and to study new nuclear species not found in nature.

A major research facility for studying nuclear interactions between heavy ions is being constructed at Michigan State University. The facility, scheduled to be completed in 1984, is based on a new kind of particle accelerator, a superconducting cyclotron with a uniquely high energy gain. The purpose of this National Superconducting Cyclotron Laboratory is to study the collisions of heavy ions, and the nuclides produced in these collisions, in a new region of energy and intensity.

In addition, the Nuclear Physics program carries out theoretical investigations of the interactions, properties, and structure of nuclei. Nuclear theory research interprets experimental results in terms of fundamental forces and also guides the planning of new experiments.

Working with the Department and the National Science Foundation, the Nuclear Science Advisory Committee developed a long-range plan for basic nuclear research. Recognizing the central importance of accelerator facilities and related instrumentation, this plan calls for a balanced mixture of new facility construction and an upgrading of existing facilities and facility utilization. During 1981, DOE plans to examine means for im-

plementing this plan to allow for a balanced national nuclear physics program capable of producing fruitful research and maintaining U.S. leadership in this field.

Research during 1981 and 1982 will concentrate on gaining detailed quantitative knowledge of nuclear structure and dynamics by studying the behavior of nuclear matter when subjected to high stresses such as rapid rotation, compression, high temperatures, and unusual ratios of neutrons to protons. Important complementary information will be gleaned on the basis of correlations among experiments employing various probes (e.g., electrons, pions, and protons).

An understanding of the fundamental interactions, properties, and structure of nuclei, and their dynamic properties and behavior under extreme conditions is growing steadily. Many accomplishments illustrate this growth. Nuclear theorists have developed a new model of nuclei that provides a framework within which many different dynamic nuclear properties can be correlated, and apparently conflicting properties can be understood. For example, some experiments indicate that entire nuclei rotate and vibrate as a unit. At the same time, other experiments indicate that individual protons and neutrons move as independent particles inside nuclei. The newly developed "interacting boson model" describes both these situations within a unifying quantitative treatment based on coordinated pairs of neutrons and protons (bosons). The model also predicts patterns of motion yet to be observed in nuclear experiments. Many independent experiments have shown that the nuclear force attempts to organize individual neutrons and protons into coordinated pairs within the nucleus.

At densities higher than those found in normal nuclei, new states of matter involving additional particles may exist. Applications of one concept of a new state in astrophysics called "pion condensate" appear to resolve outstanding puzzles associated with cooling processes in neutron stars. This new state is characterized by a special ordering of the neutrons and protons bound in nuclei, similar to the ordering of groups of atoms which occurs when iron is placed in a magnetic field. Such critically dense matter may be created in the laboratory in collisions between heavy nuclei accelerated to relativistic (extremely high) energies. Scientists at Lawrence Berkeley Laboratory's Bevalac are beginning to test these theories in experiments which, for example, measure correlations among pi-mesons and protons produced in the collision of heavy ions. At the Anderson Meson Physics Facility, nuclear physicists are seeking evidence of enhancements of special pi-meson states that should occur below critical density (if pion condensates exist).

In addition, the intense flux of neutrinos emerging from the beam stop at the Anderson Meson Physics Facility has been used to examine the fundamental processes

responsible for beta decay of nuclei. Neutrinos are particularly puzzling subnuclear particles with no electrical charge and little, if any, mass. They are, however, essential to an understanding of the weak force of nature. This force manifests itself in the beta decay of some nuclei. In the beam stop experiment, two weak reactions were studied quantitatively to provide a new and more precise statement of the physical laws of the weak force. Results of this experiment also permit direct determination of the reaction rate of the reaction responsible for essentially all of the energy released by the Sun. Two protons are combined in the Sun to create a deuteron (a nucleus made up of one proton and one neutron), a positron (anti-matter electron), and a neutrino.

One of the basic goals of medium energy nuclear physics is to use the properties of the pi-meson as a probe of nuclei in order to extract new nuclear structure information. Through the use of their intense secondary beam of pi-mesons, scientists at the Anderson Meson Physics Facility have identified a class of previously unseen nuclear states. Known as "pure" neutron configurations, these states differ from the lowest energy or ground state of a given nucleus by the promotion of neutrons and only neutrons to quantum orbits of higher energy. As such, they provide a new class of simple elementary nuclear excitations that are of fundamental importance and represent, as well, a clear test of the reaction theories for pi-mesons. Scientists have found that high spin nuclear states of target nuclei, such as carbon with large rotational motion within the nucleus, appear to be composed primarily of very simple configurations in which one and only one neutron or proton is promoted to a higher quantum orbit.

Yet another discovery was made at Lawrence Berkeley Laboratory's Super HILAC/Bevalac accelerator. Using beams of heavy ions from the accelerator, scientists there produced and identified 14 nuclides that had not been previously observed. These nuclides, which were isotopes extremely rich in neutrons, were produced by fragmentation of high calcium ions. This firmly established the method as an efficient way of producing nuclei far from stability.

The identification of neutron-rich nuclei is important because it provides very sensitive tests of theoretical predictions of nuclear masses and, in particular, predictions of the limits on the number of neutrons that can be bound to a host nucleus. The masses of some nuclei far from stability have been measured by using certain reactions in which positive pi-mesons enter and negative pi-mesons exit, and vice versa.

In May 1980, scientists at the Oak Ridge National Laboratory accelerated and transported the first beam of heavy ions in the newly constructed Holifield Heavy Ion Research Facility. An oxygen beam, with a charge state of plus six, was formed, accelerated, and analyzed. Holifield

the world's highest voltage electrostatic accelerator. When complete, the accelerator's heavy ion beams can be focused and varied in energy beyond those of any other facility. A measured buildup to full operation is now in progress.

Life Sciences Research and Nuclear Medicine Applications

Research in these areas is carried out through two independent programs under the Health and Environmental Research program. The Life Sciences program represents the only DOE program that conducts fundamental biological research in specific areas. The Nuclear Medicine Applications program focuses on the beneficial application of radiation, radionuclides, and stable isotopes in clinical nuclear medicine for the diagnosis and treatment of human diseases.

The objectives of the Life Sciences Research program are to understand the basic structure, function, and interrelationships of all main components of living organisms and terrestrial, fresh water, and marine ecosystems; to obtain basic information on the action of energy-related pollutants on humans and their environment; and to develop automated, high-resolution instrumentation and techniques for use in biological and environmental research. These objectives are accomplished through a coordinated program of research performed at national laboratories, universities, hospitals, and specialized biomedical laboratories. The resulting data support the applied efforts that are directly related to technologies, for example, the development of methods for detecting biological damage.

During 1980, biological research continued on the structure of key molecules, cell membranes, and cell components. The molecular structure of DNA, the mechanisms by which it is replicated, and its expression

regulated and transmitted from cell to cell and from parent to offspring, received special attention.

The Department plans to continue research in cellular biology during 1981 to develop cell and tissue models for interpretation of biological effects produced by toxic materials. Plans also include evaluating biological mechanisms involved in removal of inhaled particulates from the lung; expanding research on structural changes in key, pollutant sensitive, biological macromolecules when complexed with toxic agents; and supporting fundamental investigations on biological material using Brookhaven's new National Synchrotron Light Source Facility.

Nuclear medicine applications research supports the research and development of new applications of radiation and radioisotopes for the diagnosis and treatment of human diseases. Promising new approaches are tested for feasibility and, if successful, are transferred for use in clinical medicine. Without these nuclear medicine tests, noninvasive methods would not exist for diagnosing abnormalities and diseases of the heart, lung, liver, central nervous system, and other organs and tissues of the human body.

Noteworthy accomplishments in 1980 included quantitative inhalation studies conducted with nitrogen-13 and diffusion studies conducted with carbon-11-monoxide for the early detection of lung damage in persons exposed to potentially toxic agents. Efforts were expanded on research, development, and feasibility testing of new positron-labeled radiopharmaceuticals for use in tomographic (X-ray photographic) studies. In addition, new imaging systems were demonstrated for the clinical diagnosis of heart, lung, and brain function studies, as well as for basic physiological research. Research development and clinical feasibility testing of new positron-labeled radiopharmaceuticals for use in tomographic studies will be expanded during 1981 to include new nuclides for the diagnosis and treatment of human disease.

Chapter 13

Defense Programs

Introduction

The Department of Energy contributes to the Nation's security not only by helping to ensure adequate energy supplies, but also by carrying out programs that directly pertain to national defense. These programs include producing the Nation's nuclear weapons, developing military-related energy technologies, strengthening national and international safeguards against nuclear proliferation, protecting classified information, and verifying compliance with arms control treaties.

Most of the Department's defense-related work is performed at Government-owned, contractor-operated facilities, whose mission from the beginning has been the application of science and technology to problems of national security. Recognized as a valuable national resource, a number of these facilities are also directed toward the solution of an even broader range of national issues. In addition to support for the Nation's military posture of nuclear deterrence and arms control commitments, these facilities are also being used to address the need to provide a secure energy supply for the future.

The laboratories are actively pursuing solar energy research and development and new techniques of energy conservation. Expertise developed in conducting underground nuclear tests is being applied in the geothermal energy program. Knowledge and skills in the handling of nuclear materials are serving environmental, health, and safety programs. Refined diagnostics and quality control techniques developed for nuclear weapons are finding broad use in energy programs throughout the Department. Many of these advances also prove applicable to private

industry, benefiting both commercial enterprises and the Nation as a whole.

Inertial Fusion

The goal of the inertial confinement fusion activities is to determine the feasibility of inertial fusion for both nuclear weapons technology and potential energy applications. To put inertial fusion to such uses, small capsules containing deuterium and tritium fuel must be compressed, ignited, and efficiently burned. Such compression could be achieved by heating the millimeter-sized targets with either concentrated laser beams or beams of atomic particles. The inertial fusion activities have current relevance to certain aspects of weapons research and development. In addition, significant releases of thermonuclear energy, if achieved, could be of potential value either for weapons simulation or for commercial applications.

During 1980, target fuel compressions to 100 times the density of solid deuterium-tritium—within a factor of 10 of the compression required for efficient fuel burn—were reached in experiments on the Shiva glass laser system at Lawrence Livermore National Laboratory. Also, the Lawrence Livermore National Laboratory and the University of Rochester have demonstrated a 70-percent efficient conversion of the infrared light from glass lasers into shorter-wavelength green, blue, or violet light. Recent experiments at Lawrence Livermore and KMS Fusion confirm significantly improved target interaction with green light over that of red. The Nova facility now under construction at Livermore is incorporating these advances,

with the objective of demonstrating the scientific feasibility of inertial fusion using glass lasers.

The 10-kilojoule Helios carbon dioxide gas laser at the Los Alamos National Scientific Laboratory produced compressions to 20 times solid density. Helios is now engaged in interaction experiments that will allow for the first evaluation of the efficiency of CO₂ lasers in driving targets believed to be capable of reaching high gain. The 40-kilojoule Antares CO₂ laser facility at Los Alamos will test the scaling of CO₂ target coupling results with increased energy, and determine whether the attractive technology of CO₂ lasers can be used for energy applications. The Antares laser, laser hall, target building, and office complex are finished; laser assembly and testing are in progress.

In the Pulsed Power (or light ion) Development program at the Sandia National Laboratory in Albuquerque, New Mexico, experiments during 1980 achieved ion beam focusing to 1 terawatt (one trillion watts) per square centimeter, foil velocities of 20 centimeters per microsecond, and stable ablative acceleration of foils. The Particle Beam Fusion Accelerator I at Sandia National Laboratory was completed in June 1980 on schedule and within cost. Experiments on the Particle Beam Fusion Accelerator I are scheduled to begin in 1981 and are expected to demonstrate focusing to 5 terawatts per square centimeter. This would represent a critical milestone marking the threshold energy intensity required to drive targets with beams of ions.

Over the last few years, the program identified several advanced lasers that operate at short wavelengths—where the coupling of beam energy to targets is very good—with laser efficiencies adequate for energy applications. An alternative particle beam method is the acceleration of heavy ions. Heavy ions are predicted to interact with targets equally as well as light ions and to focus more readily. Both of these advanced driver technologies are now ready for test-bed development to demonstrate by the mid-1980's their potential for scaling to the energy and power requirements for driving high-gain targets.

Target experiments will be continued on Shiva and Helios to reach fuel compressions in the range of 100 to 400 times the solid density of hydrogen and to determine coupling of beam energy to targets as a function of laser wavelength. Construction of the 200-kilojoule Nova will continue, the first phase of which is scheduled for completion in 1983, allowing for evaluation of short wavelength gain scaling in 1984 and 1985. The 40-kilojoule Antares CO₂ laser will be activated in 1983; subsequent experiments will yield long wavelength scaling relationships for pellet ignition, establishing whether CO₂ is a candidate driver for a high-gain facility.

Experiments with the Particle Beam Fusion Accelerator I in the next 3 years should resolve the critical issues of ion beam transport, focusing, and target interaction.

The authorized upgrade of the accelerator is expected to provide break-even target experiments by 1986. Advanced laser technology demonstrations should lead to a 100-kilojoule short-wavelength driver within a similar period of time. Parallel development of heavy ion accelerator technology will complete the data base required for selecting the optimal driver for high-gain experiments.

Naval Reactors Development

The Naval Reactors Development program has historically been the source of much of the technology that now forms the base of the civilian nuclear energy industry. A joint effort by DOE and the Department of the Navy, it is concerned with the design and development of nuclear propulsion plants and reactor cores for naval submarines and surface warships. Operational data from existing naval nuclear ships and land prototypes are analyzed continuously and the results are incorporated into ongoing development efforts. Emphasis is placed on reliability, simplicity, and long life. The ultimate objective is to develop cores that will last the duration of a ship's term of service.

The technology developed in this program continues to have direct relevance to DOE's nuclear fission energy program. Accordingly, Naval Reactor Development is placed organizationally under the cognizance of the Assistant Secretary for Nuclear Energy.

Under the submarine propulsion reactors program, initial testing at full power was completed in the SG8 prototype reactor plant to confirm the performance of the reactor to be used in the Trident Class submarines. Developmental efforts continued on the Submarine Test Core, which will test advanced reactor fuels, poisons, and control materials. Engineering, physics, chemistry, and materials evaluations were conducted in support of the effort to extend the life of reactor plants and components.

In the surface ship propulsion reactors program, development and construction of Nimitz Class aircraft carrier propulsion plants continued, as did development of associated refueling systems and equipment. Work also proceeded on the prototype operation and testing of the longer-life advanced reactor core for deployment in guided missile cruisers. Design of the Advanced Fleet Core will utilize new concepts in fuel elements to improve performance and extend lifetime. The test support for the Virginia Class guided-missile reactor cruiser, the USS Arkansas, was completed during the year.

The supporting research and development program continued its investigation of the nuclear, physical, mechanical, and chemical properties of expended cores. Core design tests were performed and critical physics tests conducted. This information is of greatest value in developing a durable, long-lasting core.

Verification and Control

DOE is involved in a wide range of activities aimed at strengthening U.S. and international security. These include taking part in arms control negotiations, improving U.S. capability to verify compliance with nuclear test treaties, increasing U.S. understanding of foreign nuclear weapons potential and capabilities, preventing the spread of nuclear weapons technology and materials, and reviewing the effect of proposed energy-related exports on national security.

Technology and analytical programs designed to enhance U.S. capability to verify nuclear treaties retained high priority in 1980. Centered in the DOE weapons laboratories, these programs strengthen U.S. capability to detect, locate, and identify nuclear explosions conducted underground, in the atmosphere, or in space. This capability is essential for the negotiation and enforcement of nuclear arms control agreements.

Major 1980 accomplishments in DOE's verification technology program included delivery of the first flight-qualified Integrated Operational Nuclear Detection System (IONDS) for the Department of Defense's Global Positioning Satellite System, serial IONDS production, and development of a prototype National Seismic Station north of Fairbanks, Alaska (see Figure 13-1). A compact, self-contained facility for monitoring underground nuclear explosions, the station could be installed in regional networks in countries adhering to a Comprehensive Nuclear Test Ban Treaty, to augment long-range teleseismic monitoring. The Alaska station is performing well under extreme climatic and communications conditions, such as those encountered in the Soviet Union. An earlier prototype installed in 1979 at McMinnville, Tennessee, is to have some components replaced. It will then become the first of five seismic stations forming a Regional Seismic Test Network on the North American Continent.

Operation of the Regional Seismic Test Network is expected to demonstrate its effectiveness in distinguishing between nuclear explosions and earthquakes and hence demonstrating the ability to verify compliance with nuclear test treaties. It also is expected to yield valuable experience and data interpretation techniques that could be applied to networks in other countries. In a broader arms control context, deployment of even a single National Seismic Station on foreign territory would establish a valuable policy precedent for using "in-country" techniques to verify compliance with arms control and nuclear test treaties. DOE scientists also are pursuing research and development of advanced techniques for monitoring nuclear explosions. These include acoustic and electromagnetic detection of

explosion-caused disturbances of the ionosphere.

In 1980, DOE representatives participated in the Non-Proliferation Treaty Review Conference, the United Nations Committee on Disarmament, and the U.S.-U.K.-U.S.S.R. negotiations on a Comprehensive Test Ban Treaty. A DOE scientist serves on the Ad Hoc Group of Scientific Experts discussing arrangements for an International Exchange of Seismic Data which a Comprehensive Nuclear Test Ban Treaty is expected to establish. The Exchange would provide countries adhering to the treaty with data useful for verifying compliance, as well as complementing World Seismic System Network data for earthquake monitoring and prediction.

Climaxing a 3-year effort, DOE representatives took part in completion of the International Convention on the Physical Protection of Nuclear Materials. It now awaits ratification by the U.S. Senate. The Department also helped negotiate an extension until December 31, 1984, of the U.S.-U.K. Mutual Defense Agreement on nuclear cooperation.

In cooperation with the Department of Defense and the intelligence community, DOE initiated in 1980 an expansion of studies of foreign nuclear weapons capabilities. The aim of these studies is to improve U.S. understanding of the strengths and vulnerabilities of foreign nuclear forces, the threat they pose to U.S. nuclear weapons, and potential changes in the nature and size of such threat. This understanding is crucial to planning U.S. goals and strategy in arms control negotiations and to ensuring that treaty objectives are verifiable. It is equally crucial to ensuring the ability of U.S. nuclear weapons systems to perform their missions. DOE weapons expertise served U.S. policymakers during the year in negotiating arms control agreements. It also contributes to continuing U.S. and Allied discussion on the modernization of Theater Nuclear Forces in Europe.

Through its continuing review of nuclear and strategically significant exports, DOE plays a key role in implementing U.S. non-proliferation and export-control statutes and policies. In 1980, as Secretariat of the Interagency Subgroup on Nuclear Export Coordination, DOE developed a computerized data base for tracking export-control activities. Similarly, DOE and the Department of Defense are jointly developing a strategically significant technology list to improve the efficiency of the export-control process.

Among DOE's objectives in 1981-1982 are completion of the North American Regional Seismic Test Network, development of advanced nonseismic techniques for detecting underground nuclear explosions, production of advanced nuclear explosion detection sensors for spaceborne deployment, improvement of detection capability in the Southern Hemisphere, and completion of

Figure 13-1

National Seismic Station for monitoring nuclear test treaties. The station is fully automatic and transmits seismic data via satellite.

comprehensive technical assessment of foreign nuclear weapons potential and capabilities.

Defense Waste Management

The Department's Defense Waste Management program is designed to ensure the safe handling, processing, storage, and disposal of radioactive wastes generated by the Nation's defense program. Most of these wastes result from the reprocessing of nuclear reactor fuels. Others are generated during the production of plutonium components for weapons, the conduct of laboratory experiments, and the operation of reactors.

Interim Waste Operations

The objective of the DOE Interim Waste Operations program is the safe storage of high-level radioactive wastes in ways that are compatible with alternatives under consideration for long-term management and that minimize the potential for release into the environment.

Interim management involves the operation, surveillance, and maintenance of facilities for volume reduction and interim storage of wastes, as well as the construction of improved underground storage tanks. Another important part of the program is the development of processes and the construction of facilities to convert liquids to solids and to transfer wastes, when appropriate, to improved storage tanks until long-term disposal options have been selected and implemented.

Isolated facilities for storage of defense wastes are located at Savannah River, South Carolina, at Richland, Washington, and at the Idaho National Engineering Laboratory. DOE continues to reduce the volume of liquid waste, through evaporation of excess water. It then stores it in doubly contained underground tanks at Savannah River and Richland; and, after solidification, in underground bins at the Idaho National Engineering Laboratory. Ten double-shell tanks were completed last year at the Richland and Savannah River facilities. Seventeen more are scheduled for completion this year. By 1988, DOE plans to complete its programs to transfer wastes to these new double-shell tanks.

Other types of wastes are generated at these and several other DOE facilities as well. Transuranic wastes are stored in a way that permits intact retrieval for a period of 20 years. Low-level wastes are disposed of by shallow-land burial. Formal burial ground upgrading and operating criteria are scheduled to be published in 1981 and to be fully implemented by DOE.

Long-Term Waste Management Technology

The Department's program for long-term nuclear waste management requires technology development,

engineering studies, conceptual designs, tests, demonstrations, and evaluations as a basis for selecting alternatives specific to each site and for building associated facilities to implement those alternatives. Research and development are organized by waste category: high-level, low-level, transuranic contaminated (a waste contaminated with long-lived radionuclides), and airborne waste.

Long-term technology development programs for site-specific high-level defense radioactive waste are proceeding with primary emphasis at Savannah River, where construction of the Defense Waste Processing Facility could begin in 1983. A comprehensive program for alternative waste form development and selection is also under way as part of a process to choose the first waste form for implementation in 1984.

Technology development for low-level waste includes field tests of improved disposal technology and the development of stabilization techniques for sites no longer in use. This will provide further assurance that these disposal areas will remain safe in the long term, with minimal need for continuing maintenance and surveillance. Alternative disposal techniques for low-level wastes are being developed and assessed, as are methods to minimize the generation of low-level wastes, reduce their volume, and solidify them in suitable matrices. It is planned to begin demonstrations of selected techniques in 1981.

DOE is developing incineration and immobilization techniques for transuranic contaminated wastes that contain plutonium, certain isotopes of uranium, and other elements heavier than uranium. A full-scale demonstration plant using the slagging pyrolysis incineration technique is under construction. Tests using simulated transuranic waste are to be conducted in 1982. DOE has developed and demonstrated techniques and requirements for recovery and treatment of buried transuranic waste.

Airborne waste activities include the development of improved technologies to capture, store, and dispose of long-lived radioactive constituents suspended in off-gas effluents. Programs in this area are primarily aimed at developing cost-effective improvements, quality assurance, and new capabilities in areas where more restrictive standards will apply in the future.

Transportation

The objective of the defense waste transportation program is to ensure that future transportation needs are met in a safe, cost effective, and publicly acceptable manner. Toward this end, the Department has established the Transportation Technology Center at the Sandia National Laboratory in Albuquerque to help develop transportation systems and supporting technology. The center established a data base of actual transportation experience in radioactive shipments; it is also being used by the Department of

Transportation and the Nuclear Regulatory Commission.

Progress during 1980 included the initiation of a survey to determine what radioactive material is being shipped in the United States and between what points. Data obtained will be used in risk assessment and for informing state and local policymakers about shipments going through their areas. The Department has established beneficial contacts with state and local policymakers by responding in a timely manner to state requests for accurate technical information on nuclear material transportation. These contacts also help DOE keep informed of proposed state regulatory actions pertaining to these areas.

Another step forward in risk assessment last year was the development of analytical risk models subsequently used by the International Atomic Energy Agency in developing a procedure for conducting worldwide transportation risk studies. Such widespread acceptance of DOE analytical techniques permits direct comparison of risk numbers developed in different countries, as well as better utilization of foreign transportation experience.

A conceptual design was completed of a Type-B Transuranic-Contaminated Package Transporter, and model and full-scale testing was carried out of Type-A containers for contact-handled radioactive waste. A scale model of a railcar transport system was also tested, as was a crushable overpack for truck transport. The testing of physical designs and operational transport systems is emphasized to instill public confidence in the safety of equipment used in transporting nuclear materials.

The Nuclear Materials Transportation program plans to extend in 1981 most of those projects that began or continued last year. Some representative milestones for the year include preliminary design and scale-model testing of the Transuranic-Contaminated Package Transporter system for contact-handled transuranic waste and the completion of conceptual design for an optimal transport system for high-level defense wastes.

Decontamination and Decommissioning

The Department is responsible for the safe management and disposition of some 500 radioactively contaminated surplus facilities owned by DOE. These include reactors, fuel processing plants, buildings, tanks, and ground disposal facilities located at 19 sites throughout the United States and Puerto Rico.

During 1980, major program areas included surveillance and maintenance to ensure that these facilities remain in a safe condition until they are decommissioned, and the establishment of project priorities and the preparation of a program plan. Decommissioning operations began at 11 selected projects. This process will reduce the need for surveillance and, once completed, will permit

these properties to be put to alternative productive use. The program also develops methods of improving efficiency and reducing costs in facility disposition, and makes these methods available to private industry.

Nuclear Materials Security and Safeguards

The Security and Safeguards program is an integral part of DOE's national security responsibilities, which include the protection of nuclear weapons in its custody, special nuclear materials, classified materials and information, and DOE facilities and resources. The major objective of the program is to develop and implement policies, procedures, components, and systems to protect these assets against threats of espionage, theft, or sabotage. This is done primarily by:

1. Characterizing potential threats against DOE security interests
2. Developing and implementing safeguards and security policies, and appraising their effectiveness
3. Providing effective emergency response to threats or malevolent acts that endanger public health and safety
4. Developing advanced safeguards and security components and systems for DOE facilities and operations
5. Supporting U.S. nuclear non-proliferation objectives

In addition, all program elements are supported through the operation of a Department-wide security clearance program for those working at DOE facilities and on DOE programs.

Characterizing threats is the first step in the development and implementation of the security and safeguards program. Based on past experience and continuing research into the nature of potential threats, DOE is developing more comprehensive guidance concerning the capabilities and characteristics of potential adversaries. DOE also evaluates the effectiveness of its security policies at the contractor, field, and headquarters levels to ensure that its interests are not exposed to unnecessary risks.

While these policies concentrate on the prevention of threats or malevolent acts, the Department must also be prepared to respond effectively to safeguards and security incidents. Through its incident management activities, it provides the resources necessary to respond to emergencies that may result from threats or malevolent acts directed against DOE facilities or operations or from threats involving improvised nuclear explosive or dispersal devices. Also, DOE has improved its ability to respond to threats directed against its interests by establishing the capability to determine rapidly the credibility of threat messages. It

1980, a major emergency response exercise was conducted with key elements of the Department and the Federal Bureau of Investigation.

Successful performance of safeguards and security functions in the field requires that DOE supply the technology needed to protect its facilities. Of special importance is technology for the measurement and control of special nuclear materials. Among the products developed for these activities are individual components and integrated safeguards and security systems.

Last year, new systems were designed and installed at several important DOE facilities to improve physical protection and to measure nuclear materials. Improvements include integrated barrier systems, automated analytical instruments to improve accuracy and reduce measurement time, and new systems for detecting special nuclear materials, explosives, and metal contraband at entry and exit portals. All major DOE facilities conducted safeguards and security surveys. Guard force training at selected facilities included simulated armed engagement exercises.

Products from the Department's technological base directly support U.S. nuclear non-proliferation objectives. Technical assistance is given to the International Atomic Energy Agency, and safeguards components and systems are developed for facilities with various types of fuel cycles. Training courses in international physical protection, material control, and accountability are also conducted under the mandate of the 1978 Nuclear Non-Proliferation Act.

Technical and operational support to the entire program is provided by the Safeguards Analytical Laboratory and the Nuclear Materials Management and Safeguards System.

The Safeguards Analytical Laboratory provides nuclear materials measurement support to the Department by monitoring the measurement performance of DOE contractors, as well as by developing analytical standards and measurement procedures. The laboratory provides similar services to the Nuclear Regulatory Commission and to the international community on a full-cost recovery basis.

The Nuclear Materials Management and Safeguards System is a computerized system containing national data on nuclear materials information and safeguards. It provides operational support for the program and serves as a central repository for information on 18 nuclear materials vital to DOE production and defense programs (including those under safeguards control). All DOE contractors and private firms licensed by the Nuclear Regulatory Commission provide data for the system.

The system also tracks nuclear materials that the U.S. furnishes to foreign countries under international agreements. It is being modified to enable the United States to meet its formal reporting requirements to the

International Atomic Energy Agency under the terms of the U.S. offer to place selected nondefense nuclear facilities under the agency's safeguards. These reporting requirements will become effective during 1981.

Nuclear Materials Production

The nuclear fuels materials production program provides plutonium, tritium, and other isotopes for national defense programs, for DOE reactor research and development programs, and for other government agencies and industry. Other operations include receiving, storing, and processing spent fuels from production reactors, foreign and domestic research reactors, and naval propulsion reactors to recover enriched uranium and plutonium.

The three production reactors in Savannah River continued to operate at full capacity during 1980, exceeding goals for production of nuclear materials. The primary materials produced in these reactors are plutonium and tritium for defense programs. In addition, specialized isotopes are produced for other government programs and industry, including plutonium-238 for the space program for electrical power sources, and americium-241 for oil well logging and smoke detector applications. Also, the heavy water plant at Savannah River—the only facility of its kind in the country—continued to produce heavy water for DOE and other government programs, as well as for domestic and foreign use.

Last year, in preparation for a resumption in fuel processing operations at the Idaho Fuels Processing Facility in Idaho Falls, extensive maintenance was performed on the facility's fuel processing areas. The major task was the design and installation of an independent process-monitoring system (the plant protection system) in the uranium extraction process. The Department conducted a rigorous review of operating procedures and safety analyses covering plant operations during the period. Spent fuel processing resumed late last September. Enriched uranium fuels salvaged by this process from the Naval Propulsion program and other research reactors will conserve uranium through recycling as fuel for the Savannah River production reactors.

The N-Reactor at Richland, in addition to producing fuel-grade plutonium, continued generating by-product steam for the Washington Public Power Supply System. Enough steam was delivered in 1980 to supply 3 billion kilowatt-hours of electricity to the Bonneville Power Administration power grid, resulting in U.S. Treasury revenues of about \$33 million.

The Fluorinel and Storage Facility is under construction at the Idaho National Engineering Laboratory in Idaho Falls. When completed, it will provide for the receipt, storage, and dissolution of spent reactor fuel for which no other capability exists, helping to conserve

domestic uranium resources through recovery projects. By the end of 1980, construction on the project was about 15 percent finished. Completion of the facility is scheduled for 1984. By 1992, Fluorinel is expected to have processed about 10 metric tons of enriched uranium worth approximately \$350 million.

While new facilities are being built, existing production facilities must be maintained and upgraded. Last year, the Department completed its first annual reappraisal of the Facility Restoration program for upgrading its production facilities in Savannah River, Richland, Oak Ridge, and Idaho Falls. This study, a followup to the original Facilities Upgrading Study conducted in 1979, updated costs, scope, and schedules. This was necessary to upgrade production and site facilities and to eliminate the backlog of deficiencies accumulated over the past quarter century of operation. The cost of completing the program is estimated to be \$350 million (in 1981 dollars). During 1981, the Department plans to initiate the first phase of the Facility Restoration program, which includes the design and construction of two Savannah River projects intended to upgrade reactor fuel handling equipment and product processing facilities. Figure 13-2 shows the locations of these facilities.

Immediately following the accident at Three Mile Island, DOE began to assess the relevance of the accident to the nuclear materials production facilities. The Kemeny Commission's Report and the Nuclear Regulatory Commission's "Lessons Learned" document were carefully analyzed, and followup actions are being taken.

While these analyses have confirmed the safety of existing systems, they have also led to improvements. Among them are the identification of critical components for upgrading procedures and the development of more comprehensive safety plans. Greater emphasis is also being placed on the training and qualification of operators.

To coordinate better all safety activities, the Assistant Secretary for Defense Programs approved an implementation plan setting forth the responsibilities of different program offices in ensuring continued safe operation of nuclear materials production facilities. To bolster these safety efforts, he also approved a Charter for Committees on Nuclear Safety. During 1980, five of these committees reviewed operations at Richland, Savannah River, Idaho Falls, and Oak Ridge production sites. Three of them also met at both Richland and Savannah River, where they reviewed and reported on the safety of production reactor operations based on the Kemeny Commission's findings

Figure 13-2—Locations of nuclear materials production facilities

and other reports on the Three Mile Island accident; the other two reviewed and reported on the first-cycle uranium extraction system at the Idaho Chemical Processing Plant and on the U-233/U-235 fuel solution stored at the Oak Ridge National Laboratory Trust facility.

Also during 1980, the Office of Nuclear Materials Production participated with other elements of DOE and with the Department of Defense in two major planning studies which included an analysis of nuclear materials and related production operations necessary to meet a number of different stockpile requirements for nuclear warheads. These studies should benefit Government officials in determining the effects defense decisions have on the availability of various nuclear materials.

Nuclear Weapons Activities

DOE's Office of Military Application (OMA) is responsible for the research, development, engineering, and testing of nuclear weapons; production of nuclear weapons that can be used safely and reliably in the stockpile-to-target sequence; retirement and disposal of nuclear weapons from the United States stockpile; transportation of nuclear weapons to and from the Department of Defense receiving points; evaluation of stockpiled weapons and related hardware for safety, reliability, and performance; and maintenance of a capability to respond to nuclear accidents or incidents. The statutory bases for these responsibilities are the Atomic Energy Act of 1954, as amended; and the Department of Energy Organization Act of 1977, which transferred these responsibilities to DOE.

The mission of OMA is to develop and direct programs of research, development, testing, production, and reliability assessment of nuclear weapons in accordance with the Underground Nuclear Test program and the Nuclear Weapons Stockpile Memorandum as approved by the President; to direct DOE's program for the prevention of accidental or unauthorized nuclear detonations; to maintain liaison between DOE and the Department of Defense on nuclear weapons matters; and to administer DOE activities under international agreements for cooperation involving nuclear weapons.

In 1958, an Agreement on the Uses of Atomic Energy for Mutual Defense Purposes was reached between the United States and the United Kingdom. Under this arrangement, there has been a transmittal of information, including nuclear design information, and materials such as special nuclear materials and nonnuclear components of atomic weapons between both nations. This has enabled the United Kingdom to maintain a viable nuclear weapon capability and a production and laboratory complex necessary to support it.

During 1980, the United States cooperated with the

United Kingdom in the testing of United Kingdom devices at the Nevada Test Site. In accordance with discussion and exchange of correspondence between President Carter and Prime Minister Thatcher, the United States agreed to undertake a mutually beneficial program with the United Kingdom regarding the Trident submarine and missile system. This program is similar to the joint Polaris program that the United States and the United Kingdom undertook during the early 1960's. DOE and the Department of Defense are working closely to assure that the new Trident program is as successful as its predecessor.

Research and Development

Nuclear weapons research and development is conducted for DOE at three Government-owned, contractor-operated nuclear weapons design and engineering laboratories: the Lawrence Livermore National Laboratory in California; the Los Alamos National Scientific Laboratory in New Mexico; and the Sandia National Laboratories in both Albuquerque, New Mexico, and Livermore, California.

The responsibilities assigned to these laboratories by DOE include conducting nuclear weapons-related research and engineering, formulating new weapons concepts including feasibility studies, designing weapons components, developing requisite materials, and, finally, the testing and certification of nuclear weapons designs to be produced and placed in the Nation's stockpile. The nature and complexity of these activities require long-term continuity to assure quality, safety, security, and reliability. Therefore, work in particular areas such as materials development generally progresses over a time period of several years. Ongoing activities of the laboratories also include monitoring the production of nuclear weapons and conducting stockpile quality assurance and reliability testing programs.

Objectives of the research and development programs at the laboratories continue to include enhancing the safety, security, and survivability of nuclear weapons; conserving the use of special nuclear materials; and preventing technological surprise by potential adversaries possessing nuclear and other sophisticated weaponry.

DOE continues to work with the Department of Defense to ensure that an adequate nuclear weapon capability exists to fulfill the requirements of the strategic deterrent as well as meet the specific military applications of the tactical battlefield. DOE is studying the feasibility of equipping Missile X, a potential replacement for existing Intercontinental Ballistic Missile systems, and the Advanced Strategic Air Launched Missile, a system under study by the Air Force, with nuclear capability. Advanced development work, which normally precedes a formal study of the weapons concept, also continued on the Trident II and the Maneuvering Reentry Vehicle warheads.

At the request of the Department of Defense, the Lawrence Livermore National Laboratory undertook the development of a small nonnuclear warhead for the cruise missile. Up to 70 of these warheads will be carried in some versions of the Medium Range Air-to-Surface Missile, whose purpose is to neutralize airfields. The unique capabilities of the laboratory made it a logical selection to undertake the very difficult design problem which applies technologies developed for the nuclear weapons program to conventional warfare situations.

Earthquake damage was sustained in January 1980 at the sites of the Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore. Those structures housing activities involving radioactive materials performed as expected, although damage was sustained to other structures and within individual office and laboratory spaces. Essential repairs have been made, and plans exist to initiate an upgrade, commencing in 1981, of the remaining major structures, including those which sustained only limited damage.

As in prior years, the weapons program gave rise to spinoffs of technology to both national security and energy-related activities. The following examples of spinoffs to nonweapons applications illustrate the broad utility of many technologies that result from weapons program research and development as well as the wide range of activities that must be supported because of their application to nuclear weapons. In each of the examples listed, weapons program support contributed during the course of development, especially in the initial phase.

1. Aerial support missions were flown for remote sensing of Mount St. Helens for investigative and predictive purposes prior to its eruption in May. These involved thermal infrared scanning useful in detecting and monitoring heat anomalies and multispectral photography for documenting the physical conditions of the mountain. Since the purpose of the measurements was predictive in nature, limited post-eruption flights were conducted.
2. Radiation-hardened microelectronics to be used in National Aeronautics and Space Administration flights to Jupiter will be produced by Sandia National Laboratories. Radiation hardening involves fabricating components in extremely clean surroundings and chemically and physically altering their electronic structure so that incoming radiation such as is encountered by spacecraft does not permanently degrade components or hinder performance.
3. Ion implantation has sharply increased the photosensitivity and reduced the exposure energy required to store photographic images in a transparent lead-lanthanum-zirconate-titanate

ceramic device developed earlier through weapons program research. The photoferroelectric image storage device is a ceramic plate that has potential applications for nonvolatile, but erasable, photographic storage and image contrast enhancement.

4. Atmospheric Release Advisory Capability (ARAC) is a real-time DOE emergency response system for determining the trajectories of accidental atmospheric release of radionuclides. Although the original purpose for ARAC was to support DOE programs, in the aftermath of the Three Mile Island nuclear reactor accident (where it was used successfully for predictive purposes) interest arose in utilizing ARAC to address commercial nuclear power programs.

Weapons Testing

Weapons testing, an integral part of nuclear weapons research and development, is conducted at the Nevada Test Site. All nuclear tests are conducted underground in accordance with the terms of the Limited Test Ban Treaty of 1963. Since March 31, 1976, the proposed Threshold Test Ban Treaty, which limits nuclear test yields to 150 kilotons, has also been observed. In 1980, 15 announced tests were conducted, of which 1 was conducted jointly with the Department of Defense and 1 was conducted jointly with the United Kingdom.

Within the framework of national policy of maintaining a strong nuclear force to discourage attack by any potential aggressor and to provide for the Nation's common defense and security, an active research and development program including testing of nuclear weapons is being pursued. In the interest of public and environmental safety, scientific and technical experts review all proposed nuclear tests to ensure compliance with safety and containment standards. The nuclear weapons testing program is conducted in accordance with requirements of the National Environmental Policy Act.

Production and Surveillance

Seven Government-owned, contractor-operated plants¹ make up DOE's nuclear weapons production complex. With their wide range of manufacturing capabilities, these plants produce and assemble all the components needed for the Nation's nuclear weapons stockpile, including parts from uranium, plutonium, and other key

¹Rocky Flats Plant, Golden, Colorado; Bendix Plant, Kansas City, Missouri; Pinellas Plant, Clearwater, Florida; Pantex Plant, Amarillo, Texas; Mound Facility, Miamisburg, Ohio; Y-12 Plant, Oak Ridge, Tennessee; and Savannah River Weapons Facility, Aiken, South Carolina.

aterials, at extremely high levels of precision, quality, and reliability.

During 1980, the Department's weapons complex began production on a new version of the B61 air-dropped bomb, equipped with the latest technologies in safety and command and control devices. At the same time, production continued on the B61 model introduced in 1979, a bomb similarly equipped but with a different yield.

As for strategic weapons, production continued last year on warheads for the Air Force's Minuteman III ballistic missile, and for the Navy's Trident submarine-launched ballistic missile system. In addition, a major retrofit program designed to prolong the life of the Poseidon submarine-launched ballistic missile system continued on schedule.

By the end of 1980, the Department successfully reached the production levels authorized by the President. The four weapon systems produced during 1980 (exclusive of the Poseidon retrofit program) represent a substantial increase over the preceding year and prepared the Department to meet further substantial production increases in the years ahead.

Weapon Safeguards Activities

In the area of nuclear weapon safeguards activities, considerable effort is being devoted to the implementation of modern training techniques for guards and couriers. Advanced training tools like the Multiple Integrated Laser Engagement System and Small Forces Engagement Range developed for DOE have been used successfully in evaluating the effectiveness of security forces by simulating tactical force deployments in security scenarios.

Because of new weapon production and retirement requirements, there has been a significant increase in the transportation workload for these weapons. This will probably require increases in both transportation equipment and manpower.

Joint DOE/DOD Planning Study

On November 2, 1979, the Departments of Energy and Defense approved the Terms of Reference for a joint Long-Range Resource Planning study. The study reviewed the nuclear weapons planning and acquisition process, as well as the resource planning program. The study also analyzed Department of Defense resource requirements against DOE capabilities and resource requirements, and proposed guidance for a 20-year nuclear weapons resource planning program. The final report made recommendations on the projected program workload, on guidelines for resource requirements, and on an annual review and update. Both departments are currently addressing activities that would implement these recommendations.

Nuclear Weapons Complex Restoration

During 1980, DOE completed a third appraisal of the condition of its 11 Government-owned, contractor-operated facilities for the development, testing, and production of nuclear weapons. These appraisals indicated that the weapons complex had continued to deteriorate because of age and limitations in funding, and they identified the significant financial investment required to arrest this deterioration and correct the backlog of deficiencies in utilities and equipment. This effort began in 1980 and is scheduled to continue for a number of years.

Completion of Major Construction Project

Construction of the new Rocky Flats Plutonium Recovery and Waste Treatment Facility (initially authorized by Congress in 1971) was finished in 1980. The facility's completion is a significant milestone, since the complex incorporates technological advances gained through more than 25 years of experience in the handling and processing of plutonium.

Through a sophisticated recovery process, the facility operations will produce pure plutonium metal and americium oxide from recoveries of scrap and other inventories, and it will treat liquid waste from the recovery process. The facility, designed to meet the latest safety, environmental, and operational standards, is currently in the system operational testing phase, with operational startup scheduled for 1981 and full operation scheduled for 1982.

Classification

The Department is responsible for maintaining a realistic classification and declassification system for Restricted Data, Formerly Restricted Data, and National Security Information within its jurisdiction. DOE establishes and implements policy for classifying information to determine what may be declassified and disseminated in the interest of scientific and technical progress and the general public welfare without harming national security.

During 1980, classification activities focused on developing new and revised guidance in such areas as inertial confinement fusion, isotope separation technology, stockpile information, computer codes, and safeguards and security. In addition, the Department initiated a major revision to the basic overall nuclear weapon technology classification guide both to update the policy and to provide more extensive rationale and background information on policy development.

DOE is locating and screening records that may be related to the effects of radiation on health and to the conduct of past nuclear testing. This activity has been prompt-

ed by the need to be completely responsive to public concerns about possible effects of past U.S. nuclear testing on the health of people living in the region of the test sites. The Department plans to centralize all relevant documents for the public in a Coordination of Information Center after deleting classified information. The center will be located at the DOE Nevada Operations Office.

Following extensive reevaluation, DOE has issued a completely revised set of classification and declassification procedures and is developing an expanded and improved program for training DOE personnel in the overall implementation of classification policy and procedures. The

Department is also continuing to review past declassification actions.

In the coming year, the Department will place particular emphasis on the following: completion of the revision of the overall nuclear weapon technology classification guide; review and revision of the guides which define overall DOE classification policy; continuation of the major review efforts on past declassification actions as well as on records related to radiation-health effects and the conduct of past nuclear testing; and improvement of appraisal and oversight activities.

Chapter 14

International Programs

Introduction

Previous chapters have dwelt on the U.S. domestic response to the premier task of the 1980's: developing secure sources of reasonably priced energy to fuel the expansion of the U.S. economy and to reinforce this country's national security position. The midterm to long-term task centers on gradually restructuring the economy to rely more heavily on available alternative energy sources such as coal and nuclear through 1990, and synthetic fuels, solar, and—possibly—fusion energy in the years beyond. In the interim, the United States will continue to be dependent upon oil for its energy needs, sizable quantities of which must be imported from politically unstable regions of the world.

As a major oil importer, the United States cannot ignore the world oil situation. Nor can its economic health and national security be isolated from the oil-based economies of its industrial trading partners. Indeed, the long-term economic well-being and security of the Western world depends on making the necessary institutional and technological adjustments that will permit a smooth transition to alternative energy sources. Clearly, it is necessary for the United States to have an energy policy that actively considers the international aspects of U.S. energy supply. Such a policy implies:

1. Entering into cooperative arrangements with our industrial partners to reduce demand for imported oil and promote increased indigenous energy production

2. Seeking to ensure that the price of imported oil remains as reasonable and stable as possible
3. Ensuring that the costs of oil supply disruptions, including politically motivated embargoes, are not borne by one entity alone
4. Encouraging the development of alternative energy sources through collaborative bilateral and multi-lateral research, development, and commercialization efforts that further the development of U.S. and foreign technology and in which costs are equitably shared

Cooperative Arrangements to Reduce Import Dependency

A major objective of U.S. international energy policy is to reduce the global economy's vulnerability to rapidly escalating oil prices or oil supply disruptions through coordinated conservation measures, fuel switching efforts, and indigenous production. Independent action by individual nations can have some impact on achieving this goal, but the desired effects are more equitably achieved through collective action.

For this reason, the 21-nation International Energy Agency (IEA) was established after the 1973-74 oil embargo to provide industrialized nations a means for collective efforts in energy research and development, for sharing available oil supplies in the event of supply disruptions, and for encouraging demand restraint. A semi-autonomous agency of the Organization for Economic Cooperation and Development (OECD), the IEA is the principal

forum through which the United States pursues its international energy objectives. In addition, economic summits—annual meetings of the heads of state of the seven major industrialized countries (the United States, the United Kingdom, Japan, France, Canada, Italy, and the Federal Republic of Germany) and the Commission of the European Communities—are important forums for addressing broader issues of energy and economic policy in a more informal setting.

As the world moves from oil to alternative energy sources, demand reduction in the industrialized countries of the West will not by itself alleviate the world's energy problems. The developing countries form a bloc whose energy consumption will increase most rapidly in proportion to expected economic growth in the next few years. As a result, the interests of the United States and other industrialized countries in an orderly international oil market are well served by helping developing countries along an energy path that relies on renewable and indigenous energy resources as much as possible.

Industrialized Countries

The United States played a prominent role at the ministerial-level IEA meeting in May 1980, initiating many of the measures agreed to by the ministers. A significant accomplishment, spurred by a U.S. initiative, was the establishment of a system of yardsticks and ceilings to measure progress in achieving midterm oil import objectives and to allow IEA countries to manage sudden supply interruptions that do not reach the 7-percent threshold that triggers the formal IEA emergency oil-sharing system. This new system represents an important political commitment by the IEA to carry forward the decisions made at the December 1979 ministerial meeting, which established individual 1980 oil import ceilings and 1985 oil import objectives, and to deal effectively with the changing market of the 1980's.

The ministers also agreed that the IEA should undershoot its 1985 group oil import objective of 26.2 million barrels per day by as much as 4 million barrels per day, and that it should initiate a process of government-industry consultations on oil stocks to prevent uncoordinated stock policies from destabilizing the oil market. The ministers agreed to endorse the recommendations of the U.S.-sponsored International Energy Technology Group and to establish a high-level group on commercialization to accelerate the introduction of synthetic fuels. The United States agreed to chair this group as part of its commitment to foster the development of a domestic synthetic fuels industry.

In addition, the ministers agreed to endorse the IEA research, development, and demonstration strategy and the high-security scenario calling for accelerated energy

research and development efforts by member nations. Finally, the ministers agreed to request the Coal Industry Advisory Board to provide specific recommendations to the December ministerial meeting on means to increase the production, trade, and use of coal. This IEA activity provides international support for U.S. domestic coal initiatives.

Following the IEA ministerial in May 1980, an economic summit was held the following month in Venice to discuss a number of international economic issues. The Department played a prominent role in the preparation for this summit. Among the major energy decisions made at the summit were commitments to:

1. Encourage increased conservation investments in residential and commercial buildings, and accelerate fuel-switching efforts and production of more fuel-efficient vehicles
2. Make a coordinated and vigorous effort to increase the supply and use of alternative energy sources equivalent to 15 million to 20 million barrels of oil per day over the next 10 years
3. Double coal production and use by the early 1990's
4. Actively support the work and recommendations of the International Energy Technology Group, particularly the establishment of the high-level group to promote the commercialization of synthetic fuels technology
5. Reduce to 0.6 the ratio of total energy consumption to economic growth, and reduce the share of the oil component in total energy demand from 53 percent to 40 percent by 1990

In October 1980, as part of its normal schedule of meetings, the IEA governing board again met and reviewed developments arising from the war between Iran and Iraq. While the loss of supplies from these countries posed a long-term challenge to the world, the oil market was manageable over the short term, primarily because of the high stock levels built up prior to the war and declining consumption. Recognizing the possible threat of a rapid deterioration in the world oil market should the conflict continue, however, the IEA member governments agreed to take the following measures to prevent unnecessary upward price pressures on the oil market: urge both private and public market participants to refrain from any abnormal purchases on the spot market; consult with oil companies to promote a group stock drawdown sufficient to balance demand and supply in the fourth quarter; and reinforce the conservation and fuel substitution measures that were already contributing to lower demand for oil.

At the December 1980 ministerial meeting, chaired by the Secretary of Energy, the ministers reaffirmed the need for an ongoing process of collective IEA action to deal with the problems emerging from the global change in

energy supply and use patterns. Ministers focused mainly on the instabilities and imbalances of the short-term oil market situation. Acutely aware that the world is in the midst of the third oil supply disruption in 7 years, the ministers agreed to a five-point program to remove potential market pressures that might lead to higher prices. Implementation of this program is expected to cut IEA oil demand on the world market by 10 percent in the first quarter of 1981, from a previously anticipated 264 million tons to 238 million tons. This program involves:

1. Accelerating efforts to encourage the efficient use of oil and its replacement by other energy sources (oil consumption in 1980 was about 6 percent less than in 1979, and the ministers want to extend that trend)
2. Encouraging increased production of indigenous oil and natural gas
3. Discouraging undesirable purchases of oil at price levels that serve to increase market pressures
4. Drawing on stocks as necessary to maintain a balance between supply and demand in the world market
5. Adopting a system to smooth out imbalances in the distribution of oil supplies

Other important ministerial deliberations centered on longer-term measures. The ministers adopted a 19 point program for energy conservation and fuel switching to be implemented through national policies. The ministers also received the first report of the Coal Industry Advisory Board which concluded that stronger collective action is required to meet the group objective of doubling coal production and use by 1990. The board will produce a followup report advising governments on the overall potential to increase coal use and production in individual countries, and suggesting practical ways to overcome specific constraints that impede accelerated growth of the steam coal industry.

Developing Countries

The United States is taking an increasingly active role in assisting developing countries, almost all of which are being hit hard by rising energy costs. The United States seeks to make the major producer nations accept a fair share of the responsibility in sustaining world economic stability, and we have encouraged these countries to increase oil production and assist developing countries. The Department works closely with the International Development Cooperation Agency and the Agency for International Development in a number of energy technical assistance and technology transfer efforts as part of the U.S. development assistance program.

Since 1977, DOE, with policy guidance from the Department of State, has managed a cooperative program

with selected countries to conduct comprehensive energy assessments that provide a basis for national energy planning and decision-making by the host governments.

These assessments, conducted jointly by teams of energy experts from the United States and the host countries, are comprehensive technical and economic evaluations of current and projected energy needs, uses, and resources. The aim of the program is to lessen dependence on imported oil, encourage development of indigenous resources, and avoid premature or excessive commitments to high-cost, high-technology energy systems. The assessments are conducted on a fully collaborative government-to-government basis, and they entail extensive participation by both groups in the evaluation and interpretation of the results.

Assessments have been completed with Egypt and Peru and during 1980 were under way with Argentina, Portugal, and the Republic of Korea; each involving approximately 10 to 12 man-years of professional effort. Additional assessments are being discussed with other nations including Venezuela (the first OPEC country and the first country that will fully reimburse the United States for its work), Tunisia (in cooperation with the Agency for International Development), and Greece (an important North Atlantic Treaty Organization member).

Efforts to Promote Secure Supplies and Reasonable Prices

The harmful effects of dependence on imported oil were underscored in 1979 and 1980 by continuously rising oil prices. While U.S. energy security ultimately lies in decreasing this dependence, an important component of U.S. policy in the transition period from an oil-based economy to one based on alternative fuels is to attempt to encourage production of conventional energy sources throughout the world. DOE has pursued this policy with both consumers and producers and in both the oil and natural gas markets.

Natural Gas Negotiations

As a result of 3 years of negotiations between DOE, the Department of State, and producer nations, the United States for the first time has developed a natural gas import policy that calls for the importation of natural gas and liquefied natural gas (LNG) from secure supply sources at prices competitive with those of alternative fuels in U.S. markets.

This policy initiative led to the successful negotiation with Canada and Mexico of natural gas import contracts that now cover import authorizations of up to 1 trillion cubic feet per year from Canada and 300 million cubic feet per day from Mexico.

As for LNG imports—most notably from Algeria and

Nigeria—DOE and other Federal agencies have been extensively involved in formulating import policy guidelines that also require that the price of imported regasified LNG be competitive with the price of alternative fuels in the United States and comparable to the prices paid for natural gas imports from Mexico and Canada.

Alaska Natural Gas Transportation System

DOE led successful negotiations during 1980 with the producers, sponsors, and the Canadian Government on the Alaska Natural Gas Transportation System. This pipeline system will eventually provide the equivalent of 400,000 barrels per day of oil in the form of natural gas to the lower-48 states.

Progress was made during the year on obtaining financing for the Alaskan segment of the system. An agreement on the funding of the design costs for the Alaskan segment was reached between the consortium of pipeline companies that will sponsor the construction of the pipeline and the oil and natural gas companies producing Alaskan natural gas. In addition, DOE helped producers and sponsors formulate a joint statement of intent to expedite completion of a financing agreement for the Alaskan segment. Also during 1980, the number of sponsors was expanded from 6 to 13 pipeline companies, including most of the major pipeline companies in the United States.

The most important achievement during 1980 was the successful negotiation of an agreement with the Canadian Government on prebuilding most of the southern part of this pipeline system (from central Alberta to Iowa in the East and to Oregon in the West) before the rest of the system is finished. The prebuild will enable Canadian gas exports (equivalent to 200,000 barrels per day of crude oil) to be delivered to the lower-48 states. Construction of the prebuild section has begun, and initial deliveries of Canadian export gas are expected to begin in early 1981. These gas exports will be phased out when Alaskan gas starts flowing through the system.

Information and Analysis

International energy policies that are developed and carried out by the Department require accurate and timely information and analysis. For example, during the Iran-Iraq war the spot oil market required active daily monitoring to enable the Secretary of Energy to react quickly to rapid price increases that so often occur during temporary oil supply interruptions. In addition, in-depth, long-term energy supply and demand projections provide the framework required to discuss cooperation with other consuming countries on reducing dependence on imported energy supplies.

The methods used to analyze the world energy situation range from simple accounting techniques to complex models, all tempered by experienced judgment. All sources of information are used, including technical literature from trade and professional journals and the most sophisticated intelligence information available. This combination of sources and methods provides the analytical underpinning for the wide range of international energy activities within the Department and supports the Secretary of Energy, the assistant secretaries, and other high-level Department officials in their policymaking process.

Collaborative Research and Development Agreements

Collaborative efforts on demand restraint and pricing policies have thus far helped to avoid any major supply and economic disruptions. Nevertheless, true long-term energy security can only be achieved through the development of alternative energy sources.

To avoid a future scramble for limited and increasingly costly world oil supplies, the United States has entered into more than 50 bilateral and 35 multilateral energy research and development agreements. All of these agreements are directed toward collaborative programs that accelerate development and commercial application of energy technologies that have a significant ability to replace imported oil; that enhance the development of alternative energy sources; that reduce research and development costs to the United States; and that maintain U.S. leadership in energy technology.

Brazil

Brazil has undertaken numerous cooperative efforts in the last 7 years to reduce its heavy dependence on the world oil market. An extensive research and development program in alcohol fuels is under way, and Brazil is currently reviewing DOE proposals for cooperation in biomass research and development with emphasis on alcohol fuel production and industrial energy conservation.

Also during 1980, DOE conducted discussions and workshops on coal and solar energy in Brazil, stimulating interest in U.S. technology on the part of two of their states that are planning to develop their coal resources and utilize solar energy in industrial and agricultural applications. These activities are expected to lead to commercial opportunities for U.S. industry and reduction of Brazilian dependence on imported oil.

Canada

Canada has more than 13 years experience with tar sands and heavy oil technologies. As part of a 1979 agree-

ment, DOE is collaborating with the Canadian Government and the Provinces of Alberta and Saskatchewan on heavy crudes and tar sands characterization through seminars and a joint study.

Israel

In August 1980, DOE and Israel signed three agreements for cooperation providing for projects in luminescent solar collector research, passive solar cooling tests, and demonstration of an energy-producing anaerobic digestion system developed in Israel. Discussions are under way on possible cooperation in solar ponds and biomass research.

Italy

As part of an intergovernmental memorandum of understanding signed with Italy in October 1979, the Department in 1980 began a number of technological cooperation projects in coal technology, solar energy, and electric power transmission. The cooperative coal and solar projects, in particular, offer attractive future commercial cooperation opportunities as well as provide alternatives to Italy's heavy dependence on imported oil. Also during the year, an agreement with Italy's national utility for cooperation in geothermal research and development was extended for 5 years.

Mexico

As part of the 1979 memorandum of understanding between Mexico and the United States that provides for continued cooperation in science and technology, seminars were held during 1980 in the areas of enhanced oil recovery and passive solar housing design. The Department's Solar Energy Research Institute initiated a series of meetings with Mexican solar energy officials on solar energy planning, and is continuing its cooperation in the geothermal area.

Nigeria

Nigeria is a major supplier of low-sulfur light crude oil and petroleum products to the world market. However, production projections indicate a gradual decline unless offshore resources are exploited. Also, increased domestic consumption in Nigeria could further reduce the amount of oil available for export unless efforts are made to shift Nigeria's economy away from oil.

In July 1980, DOE and Nigeria signed a memorandum of intent to identify and establish cooperative projects to increase oil and natural gas production and expand the use of alternative energy sources. The Department has proposed projects in coal and oil production and solar

energy research. The Nigerian Government was reviewing these proposals at the end of 1980. It is expected that Nigeria will reimburse the United States for essentially the full cost of any major projects that are undertaken.

People's Republic of China

In March 1980, the United States and the People's Republic of China agreed on a work plan to implement the Mondale-Deng agreement to establish a cooperative program in hydropower development and water resource management. China has a major untapped hydro potential exceeding 550,000 megawatts. In late 1980, the first of the work plan activities involving participation by the U.S. Army Corps of Engineers, the Water and Power Resources Service, the Tennessee Valley Authority, and the Bonneville Power Administration got under way. The potential in trade for the U.S. private sector could exceed \$1 billion, and China's exposure to U.S. capabilities and construction management concepts and practices should enhance the competitiveness of U.S. firms for future projects. Other areas in which cooperation may develop include coal, oil, oil shale, and nuclear power.

Saudi Arabia

A 1977 agreement between the United States and Saudi Arabia provides for a series of solar projects, with each country sharing equally the cost of the \$100 million program over a 5-year period. U.S. industry is carrying out the major part of the work. During 1980, construction began on a 350-kilowatt photovoltaic power system for a Saudi village. When finished in 1981, this will be the world's largest photovoltaic system. Construction also began on four solar-powered cooling systems in Arizona that are scheduled to be operational in 1981. In addition, five desalination projects were launched and several proposals aimed at applying solar energy technologies to the agricultural sector were developed. Finally, plans were completed for an international solar energy workshop for developing countries to take place in Saudi Arabia in March 1981.

Venezuela

In March 1980, DOE and Venezuela signed a general agreement on scientific and technological cooperation in energy research and development. The 5-year bilateral agreement provides for cooperation in solar and geothermal energy, hydropower, and petroleum and coal development. The initial emphasis will be on unconventional oil development.

Both Venezuela and the United States have extensive heavy oil deposits that can significantly expand and extend

the world's oil supplies if they can be developed economically. Venezuela and the United States also have research, development, and demonstration programs in enhanced oil recovery and, under the agreement, will exchange personnel and information on heavy oil production and upgrading and conduct joint studies and projects. Six specific project annexes relating to the characterization and production of heavy crudes and supporting technology were initiated in the latter part of the year.

International Energy Agency

A prime example of mutually beneficial International Energy Agency (IEA) cooperation is the recent agreement among the United States and other IEA members on a research, development, and hardware testing project expected to identify major energy conservation opportunities in the pulp and paper industries. This project is expected to result not only in energy savings but also in lessened demand for low-sulfur fuels.

DOE played a major role in establishing, organizing, and carrying out the initial work of the International Energy Technology Group, established at the Tokyo Economic Summit in 1979. The group, which has been incorporated into the IEA/OECD framework, will analyze national commitments to synthetic fuels production in the OECD countries, with emphasis on commercial-scale production of synthetic fuels in member countries through the year 2000, and recommend additional or accelerated national and international actions required to meet projected world energy demand. In October 1980, the group initiated a data-gathering effort expected to be completed in the spring of 1981 to project capacity and demand.

Under the leadership of DOE's Office of International Affairs and Office of Energy Research, IEA completed and published its research and development strategy. This strategy, approved by the IEA Governing Board in May 1980, identifies technologies that have significant impact on reducing oil imports, indicates the additional security that can be gained from their deployment, and proposes that IEA member countries accelerate development of these and other technologies in their national programs as well as in the IEA cooperative program. In 1981, the IEA member-countries' national research and development efforts and the IEA collaborative research and development program will be examined in relationship to the strategy to make recommendations for national and IEA actions to ensure that the programs are contributing at a maximum rate to meet member and world energy needs.

Federal Republic of Germany/Japan

In July 1980, the United States, the Federal Republic

of Germany, and Japan signed agreements to fund the construction of an advanced synthetic liquid fuels plant in Morgantown, West Virginia. The Solvent Refined Coal project (SRC-II) is the first internationally sponsored commercial demonstration of synthetic fuel technology. Germany and Japan will each pay 25 percent of the total cost of the project which is currently estimated at \$1.5 billion. If successful, this demonstration could lead to a commercial industry expected to make a major contribution to the 1992 U.S. goal of 2 million barrels per day of alternative liquid fuels. When completed in 1984, the plant will convert 6,000 tons per day of high-sulfur coal into the equivalent of 20,000 barrels of oil and may be expanded to 60,000 to 80,000 barrels per day by modular additions to the plant.

Nuclear Energy Cooperation and Non-Proliferation

During 1980, DOE continued to carry out its responsibilities as provided in the Atomic Energy Act of 1954 as amended and the Nuclear Non-Proliferation Act of 1978, to minimize the spread of nuclear weapons and to create a stable international environment for the peaceful uses of nuclear energy. The Department participated with the Department of State in negotiating new and amended agreements for cooperation in the civil uses of nuclear energy with other nations and the International Atomic Energy Agency (IAEA).

The Department was also active last year in continuing technical exchanges in a wide variety of nuclear-related fields, both bilaterally and multilaterally, under the auspices of the IAEA and the Nuclear Energy Agency of the OECD. Such exchanges are an important element in maintaining U.S. technological leadership and in fostering an open, effective working relationship with other nations on nuclear energy issues.

As provided by law, DOE continued in 1980 to exercise a major role in administering aspects of U.S. nuclear export policy including approvals of contracts for the sale of special nuclear materials and U.S. enrichment services to foreign nations, participation in reviews of export licenses for equipment, reactors, and materials, and approvals of retransfers by foreign governments of U.S.-origin nuclear materials.

U.S. policy has long recognized that if nuclear energy is to reach its full potential as an alternative to imported oil, there must be effective international arrangements to minimize the spread of nuclear weapons. Chapter 15 provides a detailed discussion of DOE's statutory non-proliferation responsibilities.

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Chapter 15

Nuclear Non-Proliferation

Introduction

Section 602 of the Nuclear Non-Proliferation Act of 1978 (NNPA) requires that the Department of Energy's *Secretary's Annual Report to Congress* include views and recommendations regarding non-proliferation policies and actions for which DOE is responsible. The Act also requires a detailed analysis of the proliferation implications of advanced enrichment and reprocessing techniques, advanced reactors, and alternative fuel cycles.

DOE plays a central role in promoting these goals. Under the Atomic Energy Act of 1954, as amended, and the NNPA, the Department has a number of responsibilities, including:

1. Participating with the Department of State in negotiating "agreements for cooperation" in the peaceful uses of nuclear energy with foreign nations and international organizations
2. Joining other agencies to reach an executive branch judgment regarding the issuance of export licenses by the Nuclear Regulatory Commission
3. Assuming the lead role in processing "subsequent arrangements" pursuant to the U.S. Non-Proliferation Act of 1978, and in controlling nuclear technology exports under DOE regulation 10 CFR 810
4. Distributing and controlling special nuclear materials and equipment
5. Participating in bilateral and multilateral cooperation with foreign nations and organizations to promote the peaceful uses of nuclear energy

Agreements for Cooperation

The Nuclear Non-Proliferation Act of 1978 requires DOE to provide technical assistance to the Department of State in negotiating new agreements for cooperation in the peaceful uses of atomic energy and in renegotiating existing agreements to incorporate updated non-proliferation provisions.

DOE and the Department of State, in consultation with the Arms Control and Disarmament Agency (ACDA), have developed a draft model agreement that satisfies the requirements of the NNPA. When modified as appropriate to accommodate the individual programs and policies of cooperating countries, this model serves as the basis for negotiations.

DOE joins the Department of State, in consultation with ACDA, in planning and conducting negotiations of such new or revised agreements. Upon completion, any proposed agreements or amendments must be submitted by the Secretaries of State and Energy to the President for his approval, along with an unclassified Nuclear Proliferation Assessment Statement prepared by ACDA. After signature by the United States and the country concerned, the amendments or agreements and the ACDA statement are submitted by the President for congressional review (as required by the Atomic Energy Act of 1954, as amended).

During 1980, renegotiated agreements or amendments to existing agreements were initialed or signed with Canada, Colombia, Indonesia, and the International Atomic Energy Agency (IAEA) and new agreements were

concluded with Morocco, Peru, and Bangladesh. Negotiations continued with the European Community and several countries around the world. The Department of Energy participated in all of these negotiations.

In addition, the United States concluded a project and supply agreement with the IAEA and Malaysia involving the transfer of a research reactor and nuclear fuel to Malaysia pursuant to the U.S.-IAEA Agreement for Cooperation, as amended.

Views and Recommendations

In the year ahead, DOE will continue to work closely with the State Department to maintain the momentum of the negotiation schedule. Emphasis will be on continued dialogue with such key nuclear trading partners as EURATOM, Japan, Korea, Sweden, and others.

Subject to policy directions to be established, the U.S. will emphasize its contention that the appropriate updating of the agreements will not only foster non-proliferation objectives but will also bring about even closer nuclear trade and cooperation with the countries concerned.

Technical Exchange

Introduction

The United States engages in extensive technical cooperation in the peaceful uses of nuclear energy with other nations. Such exchanges help domestic programs by making foreign technical developments available and bringing foreign technical and financial participation into domestic projects. They also assist the United States and the international community in exploring alternative fuel cycle approaches, which may offer non-proliferation advantages. Furthermore, U.S. willingness to participate in and to support technical cooperation in the civil sphere is viewed abroad as evidence of support for implementing Article IV of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).

Article IV calls on states party to the treaty to facilitate the fullest possible exchange of equipment, materials, and scientific and technological information on the peaceful uses of nuclear energy. Article IV also states that those parties to the treaty that are in a position to do so shall also cooperate in contributing to the continuing development of nuclear energy for peaceful purposes.

Bilateral Exchanges

Bilateral exchanges take place under the provisions of agreements for cooperation in the peaceful uses of nuclear

energy. Pursuant to such agreements, the United States and cooperating countries conclude technical exchange agreements providing for mutual transfers of technical information, visits by personnel, and collaboration in mutually agreed projects.

Presently, the United States has technical exchange agreements on reactor development with Canada, the European Community, the Federal Republic of Germany, France, Japan, Switzerland, and the Soviet Union. Bilateral technical exchange agreements in radioactive waste management are in force with Canada, Germany, and Sweden.

Radioactive waste management cooperation is also taking place under liquid metal fast breeder reactor (LMFBR) agreements with Japan and the United Kingdom. The *Second Annual Report on Nuclear Non-Proliferation*¹ discussed changes made in bilateral technical exchange agreements to accommodate non-proliferation considerations, including U.S. guidelines concerning cooperation in those areas of waste management with a possible relationship to the operation of reprocessing plants.

The major bilateral development in 1980 was the renewal of the waste management agreement with the Federal Republic of Germany. Its expanded scope includes the study of terminal disposal of spent power reactor fuel, which is of non-proliferation interest to the United States. It also includes waste preparation, decontamination and decommissioning, characterization of geologic disposal media, disposal in geologic formations, operational and transportation requirements, and the study of environmental, safety, and public acceptance issues related to waste handling.

The United States also continued to cooperate with the United Kingdom on liquid metal fast breeder reactors. This agreement covers fuel cycle activities, waste management, and the application of IAEA safeguards. Three 5-year project agreements covering joint work on fuel and fuel cladding performance and on head end shearing were signed in 1980. U.S. and U.K. officials are currently discussing additional cooperation in systems design and RD&D. Participation in this agreement provides evidence of U.S. commitment to the evolutionary development of advanced nuclear fuel cycles and reactors with due attention to their non-proliferation implications and safeguards requirements.

An international meeting was held in November 1980 at which the U.S. sponsors (DOE, Electric Power Research Institute, Nuclear Regulatory Commission, and General

¹U.S., Department of Energy, *Second Annual Report on Nuclear Non-Proliferation*, (Washington, D.C.: Government Printing Office-1980). [S-0010R1]

Public Utilities) of the Three Mile Island Information and Examination program discussed plans to assure that the unique learning opportunity associated with the TMI accident will be fully utilized. The foreign representatives attending the meeting were invited to identify portions of the program they were interested in, and to contact the lead organizations involved. It is anticipated that some bilateral cooperation associated with the TMI project will be started in 1981.

Multilateral Exchanges

The IAEA is a major channel for multilateral cooperation with other nations in peaceful uses of nuclear energy. The United States participates actively in IAEA technical seminars and meetings and is a major contributor to its technical assistance program. The main objectives of this program are to promote the transfer of skills and knowledge relating to the peaceful uses of nuclear energy and to aid recipient countries in carrying out their atomic energy activities more efficiently and safely.

DOE also participates in multilateral exchanges with other advanced countries through the Nuclear Energy Agency of the Organization for Economic Cooperation and Development.

Views and Recommendations

The United States should continue to support bilateral and multilateral cooperation in the civil uses of nuclear energy. Such cooperation leads to a more effective working relationship with other nations on nuclear energy issues. It provides evidence of support for implementing Article IV of the NPT and will promote adherence to the NPT.

As indicated above, such international cooperation is also an important element in maintaining U.S. technological leadership in the civil uses of nuclear energy. Technological prowess is a key element in U.S. ability to persuade other nations to support an effective international non-proliferation regime.

Non-Proliferation Treaty Review Conference

The Second Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons was held in Geneva, Switzerland, from August 11 to September 7, 1980.² The treaty established the mandate of the review

conference: to review the operation of the treaty to assure that the purposes of its preamble and other provisions are being realized.

The non-nuclear-weapons states party to the treaty commit themselves not to manufacture or otherwise acquire weapons or nuclear explosive devices. They also agree to accept IAEA safeguards on all their peaceful nuclear activities. They do this in exchange for commitments by the nuclear weapons states to make progress toward ending the arms race and beginning nuclear disarmament, and to recognize the right of all parties to use nuclear energy for peaceful purposes under appropriate safeguards.

Of the 114 countries that are parties to the treaty, 75 participated in the review conference (including all parties that are conducting any significant nuclear activities, except Taiwan). The U.S. was represented at the Conference by the Departments of Energy, State, and Defense, and the Arms Control and Disarmament Agency.

The review conference carried out its mandate through an intensive analysis of the operation of the treaty and provided an opportunity for a thorough exchange of views on the progress toward the fulfillment of the treaty's objectives in the 5 years since the previous review conference. Unlike the earlier one, the 1980 conference did not issue a final declaration. However, in the course of the deliberations, the participants at the conference strongly reaffirmed their dedication both to the treaty itself and to its objectives and to the goal of universal adherence to the agreement.

International Nuclear Fuel Cycle Evaluation

The International Nuclear Fuel Cycle Evaluation (INFCE) was proposed by President Carter in April 1977 to undertake an international review and reexamination of the technical aspects of the nuclear fuel cycle and of the proliferation implications of alternative fuel cycle arrangements. In proposing INFCE, the United States recognized that the effort to control the problem of proliferation requires a broad base of international understanding and cooperation. The U.S. felt that international fuel cycle development could benefit if nations were to review systematically means by which future nuclear power programs should evolve under terms that support the non-proliferation objective.

INFCE began in October 1977 at an organizing conference in Washington, and concluded in February 1980 at a final plenary meeting. Sixty-six nations and five international organizations participated in this study, whose work was carried out by eight working groups and a technical coordinating committee made up of the 22 working group

²The first was held in the same city in May 1975.

co-chairmen. The findings were presented at the final plenary conference in February 1980.

The Department of State led United States participation in INFCE, with the assistance of an interagency INFCE Management Committee composed of representatives from the Departments of State and Energy, Arms Control and Disarmament Agency, and the National Security Council. DOE provided the basic technical input to U.S. participation. In addition, input was provided by individual experts from the Nuclear Regulatory Commission and the Environmental Protection Agency. Periodic consultations were held with the private sector.

Although consensus was not reached on all issues, INFCE served to heighten the global awareness of the risks of proliferation and the implications of different technical and institutional choices. Also, in its final report INFCE reached a number of conclusions which, from the U.S. perspective, provide elements for follow-on studies, negotiations, and points of departure for fuel cycle planning. Some of the most important of these conclusions are:

1. Effective measures can and should be taken to minimize the dangers of nuclear weapons proliferation without jeopardizing energy supplies or the development of nuclear energy for peaceful purposes.
2. There are substantial proliferation dangers associated with weapons usable materials and the technologies that produce them. New protective measures, including improved safeguards, will be required to cope with any fuel cycles involving significant amounts of weapons-usable materials. Sensitive new fuel cycle facilities should be designed from the start to facilitate the application of effective safeguards.
3. Uranium enrichment capacity will be adequate through the 1990's. New capacity can be brought on stream in sufficient time to meet the demand that may develop thereafter.
4. There will be adequate uranium resources to sustain a once-through fuel cycle until the end of the century. The economic attractiveness of recycling plutonium in thermal reactors is not likely to be large.
5. Interim and long-term spent fuel storage are viable economic and non-proliferation alternatives to reprocessing.
6. The constraints that now apply to reprocessing and to separated plutonium at the international level need to be reinforced by other new protective mechanisms, including arrangements for placing excess plutonium under international custody.

It must be stressed that INFCE was conceived as a technical and economic study whose results are non-

binding; it was not a negotiation or an exercise designed to develop a precise roadmap for future policy directions. Accordingly, INFCE's ultimate impact will depend on two factors: the degree to which participating states take INFCE findings into account in planning their respective nuclear power programs, and the degree to which the international community translates these findings into new fuel cycle and safeguards arrangements as well as political understandings.

Post-INFCE Consultations

Now that INFCE is over, the U.S. is holding exploratory conversations with a number of its key nuclear trading partners on desired directions in future non-proliferation policies. There is a close link between these efforts and the ability of the United States to renegotiate successfully its nuclear agreements as called for by the NNPA.

In this context, cooperating nations have given substantial emphasis to the view that greater predictability must be introduced into the terms of nuclear trade, including the exercise of supplier consent rights (such as approvals of retransfers, reprocessing, and storage of U.S. supplied fuels). The United States has long been a major supplier of nuclear fuels and equipment and has emphasized its determination to help meet the needs of cooperating nations that accept desirable non-proliferation commitments. The Nation has also striven to provide its trading partners with greater confidence and predictability as to how the terms of agreements will be exercised.

Other sections of this report discuss specific issues and activities in more detail.

The United States as a Reliable Supplier of Nuclear Fuels

Introduction

Since nuclear power can help many countries in their efforts to reduce their dependencies on imported oil, the U.S. role in helping these foreign efforts can be quite significant to the global energy picture. Indeed, the strengthening of the United States' credibility as a reliable and attractive supplier of nuclear fuel and equipment to nations complying with non-proliferation conditions is an essential component of both non-proliferation and energy policies.

Recognizing that a single mechanism will not serve in all circumstances, the United States has examined several approaches for restoring confidence to the field of nuclear trade and has striven to achieve improvements in its export licensing process. The Nation continues its efforts to

modernize and expand domestic enrichment capacity, and participates in bilateral as well as multilateral discussions all aimed at identifying ways greater confidence can be restored to civil nuclear trade.

Developments During 1980

The United States has taken several recent actions to streamline the procedures for reviewing and issuing export licenses for nuclear fuel, certain nuclear reactor components, and dual-use items of equipment for nuclear powerplants.

The Nuclear Regulatory Commission accepted the executive branch recommendation that the initial core and three reloads or five reloads of fuel be issued for reactors to countries that meet non-proliferation requirements. For this group of countries, the need for individual licensing of exports of components for U.S.-supplied reactors has been eliminated and the licensing procedures for export of dual-use items (such as computers) have been streamlined. In addition, legislation was enacted during the year eliminating ceilings on low-enriched uranium supply in U.S. agreements for cooperation with NPT parties.

Multilateral Arrangements

The United States seeks to develop, with other supplier nations, multilateral arrangements to increase secure access to adequate and timely nuclear fuel supplies for buyers prepared to accept non-proliferation commitments.

The International Nuclear Fuel Cycle Evaluation identified two potential arrangements for further evaluation. The first was a nuclear fuel bank with supplier and consumer state membership. Such a bank would hold a stockpile of natural and low-enriched uranium, or rights to acquire such uranium, which could be made available to consumer states suffering interruptions of supply for reasons unrelated to fulfillment of non-proliferation obligations. The second concept was a backup or safety net arrangement, which would provide commercial or governmental sharing (at the national, regional, or worldwide levels) of supplies if minor or even major shortages or disruptions of supply were to occur. Existing commercial arrangements and national stockpiles would be used whenever possible.

Fuel bank and safety net concepts and other ideas of interest are expected to be discussed in connection with the IAEA's newly established Committee on Assurances of Supply. It met for the first time in Vienna in September. It is hoped that the committee will provide a useful forum for further discussions of ways in which both consumers and suppliers can enjoy greater confidence in their relations. It will meet again in March 1981.

Views and Recommendations

The United States should continue to consult actively with other nations on ways to restore confidence in international nuclear trade, with particular attention being accorded security of supply. Improvements in the U.S. export licensing process should be implemented so that nations abiding by their non-proliferation obligations can be assured that their fuel needs will be met on a timely and reliable basis.

The IAEA Expert Group on International Plutonium Storage

During 1980, the Department of Energy continued its support of U.S. participation in the IAEA Expert Group on International Plutonium Storage (IPS). This group reviewed preliminary drafts of possible agreements that might be used to establish an IPS. In addition, it embarked on a study of the relationship between the existing IAEA safeguards system and an international plutonium storage system.

Two technical advisory groups set up by the expert group continued to examine such issues as the research uses of plutonium,³ the quantitative starting point of an international store, the forms in which plutonium might be stored and transported, and the division of responsibility between a national operator of a store and an IPS officer at an IPS store. DOE contributed significantly to the U.S. effort to evaluate and to define positions on all of the issues.

Views and Recommendations

The U.S. should continue to participate actively in the IAEA's study of international plutonium storage in order to ensure that any such system will contribute to a credible and effective non-proliferation regime.

Implementation of U.S. Non-Proliferation Policy

Export Controls

Pursuant to the Nuclear Non-Proliferation Act of 1978, the Departments of Energy, State, Defense, and

³Plutonium is created by the capture of a neutron by U-238. Plutonium with a high ratio of Pu-239 is used in nuclear weapons. Pu-240 is a fertile isotope, the presence of which complicates (but does not prevent) the construction of nuclear weapons because of its high rate of spontaneous fission. Plutonium can be used to fuel reactors.

Commerce as well as the Arms Control and Disarmament Agency and the Nuclear Regulatory Commission established interagency procedures for reviewing subsequent arrangements involving nuclear materials and exports of nuclear material and equipment licensed by the Nuclear Regulatory Commission.⁴

In 1980, a total of 170 nuclear export license applications were referred to the executive branch by the NRC. The executive branch provided its view to the NRC on 180 applications. In addition, 295 applications were approved generically by the executive branch and processed by the NRC. As of December 31, 1980, 115 applications were undergoing executive branch review.

The criteria by which the executive branch evaluates export licenses are mandated by the Nuclear Non-Proliferation Act of 1978. Section 128 of the Atomic Energy Act, as amended by the NNPA, now requires (as a condition for continued exports from the United States to any non-nuclear-weapons states of source material, special nuclear material, nuclear production or utilization facilities, and any sensitive nuclear technology) that, at the time of export, IAEA safeguards be maintained in the recipient state with respect to all of its peaceful nuclear activities.

Subsequent Arrangements

As provided in the Atomic Energy Act of 1954, as amended, the Department of Energy has primary responsibility in the executive branch for the analysis and, if appropriate, approval of subsequent arrangements pursuant to agreements for cooperation concerning the peaceful uses of nuclear energy. These subsequent arrangements involve, for example, the approval of reprocessing of U.S.-supplied materials by foreign nations, the retransfers between nations of U.S.-supplied nuclear materials, and the execution and assignment of supply contracts for nuclear materials.

During calendar year 1980, 263 subsequent arrangements were reviewed and approved. Six cases involved the transfer of spent fuel from Japan, Sweden, and Spain to the United Kingdom or France for reprocessing. Under another subsequent arrangement the agreement was extended for 1 year between the United States and Japan for the reprocessing of a limited quantity of U.S.-origin spent power reactor fuel at the Tokai Mura plant.

Each of the approvals of transfers for reprocessing were made on a case-by-case basis, in which the non-proliferation credentials of the requesting countries were considered along with the particular circumstances in-

volved (such as the existence of contracts predating current U.S. policy and actual spent fuel storage requirements in the requesting country's facilities). During 1980, the United States continued to explore in discussions with several countries ways in which such retransfers might be handled so as to provide greater predictability and a broader consensus on non-proliferation and related fuel cycle concerns.

Finally, in December 1979, after review and approval of a subsequent arrangement, the Department of Energy signed a contract with Italy for the sale of 20,000 metric tons of depleted uranium. This material will be enriched in France to a normal assay of 0.7 percent uranium 235 for later use in nuclear power programs under the U.S.-EURATOM agreement for cooperation. The value of this contract to DOE is approximately \$160 million. The first of many deliveries scheduled over a 3-year period took place in October 1980.

Views and Recommendations

The exercise of U.S. consent rights, including approvals of retransfers and reprocessing, has been a particularly sensitive issue in U.S. relationships with a number of its allies. As noted, current U.S. policy calls for granting such approvals on a case-by-case basis.

Several partners have requested that the United States move away from such an approach and substitute one providing U.S. approvals on a longer term and more predictable basis. It is recommended that the Nation continue to explore with its partners whether greater predictability can be introduced into the exercise of such consent rights.

Cooperation in Strengthening International Safeguards and Physical Security

Safeguards

The U.S. program of technical assistance to the IAEA safeguards program—managed by DOE and funded by the Department of State—responds to urgent needs identified by the IAEA Director General.

Fifty projects were completed in 1980, bringing the total completed projects under the program to 165. During 1980, 14 U.S. cost-free experts were provided to serve under 1-year contracts with the IAEA. Four high-level neutron coincidence counters and one "active well" coincidence counter also were furnished to the IAEA and are being used in inspections for the verification of quantities of plutonium. A segmented gamma scanner was provided to the IAEA Safeguards Analytical Laboratory

⁴These procedures were published in the *Federal Register*, June 9, 1978.

ibersdorf, Austria, and is being used for safeguards ... say of plutonium-bearing laboratory waste.

As required by the NNPA, DOE, in cooperation with IAEA and in consultation with NRC, conducted an international training course on state systems of accounting and control of nuclear material. The course was attended by 27 students representing 19 countries and international organizations. Preparations were also undertaken to conduct a third international training course on the physical protection of nuclear materials in January 1981.

Security

During 1980, the Convention on the Physical Protection of Nuclear Material was before the Senate for its advice and consent to ratification. On August 22, 1980, the Department of State submitted proposed implementing legislation to the Congress. A more detailed discussion of this convention appears in the already-cited *Second Annual Report on Nuclear Non-Proliferation*.

The U.S.-IAEA "Voluntary Offer" Safeguards Agreement

On July 2, 1980, the Senate gave its advice and consent to ratification as a treaty an agreement between the United States and the IAEA to permit the latter to apply its safeguards to all nuclear activities in the United States, excepting only those with direct national security significance.

Even though nuclear weapons states party to the NPT are not required to accept international safeguards on their peaceful nuclear activities, the United States announced in 1967 that it would voluntarily accept IAEA safeguards. It did this to further the goals and objectives of encouraging the widest possible adherence to the NPT and of allaying concerns expressed by key non-nuclear-weapons states that the safeguards being applied to them would place them at a commercial disadvantage.

The agreement to implement the offer was negotiated by DOE's predecessor agencies in collaboration with the Department of State and ACDA and was approved by the IAEA board of governors in September 1976. The agreement stipulates that the United States will provide the IAEA with a list of facilities eligible for safeguards from which the IAEA will designate the facilities in which it wishes to apply safeguards. The United States brought the agreement into force on December 9, 1980, by presenting the IAEA with the instrument of ratification signed by President Carter and the list of facilities eligible for safeguards in the U.S.

Views and Recommendations

To strengthen its safeguards system, the United States should continue to provide financial, technical, and political support to the IAEA. The U.S. should also ratify and implement as soon as possible the Convention on the Physical Protection of Nuclear Materials and urge other nations to do the same. And it should facilitate the application of the voluntary safeguards agreement, which permits the IAEA to apply its safeguards to all nuclear activities in the U.S. excepting those with direct national security significance.

United States Spent Fuel Storage Policy

Introduction

By supporting international cooperation in spent fuel storage, U.S. policy has sought to encourage other nations to avoid premature commitments to the reprocessing of spent nuclear fuel and the use of plutonium fuels. This approach is designed to provide time for the international community to evaluate various technical and institutional measures to improve the proliferation resistance of the nuclear fuel cycle. Also, by providing a viable alternative to premature reprocessing, the policy has sought to discourage the spread to additional countries of sensitive facilities; and, thereby, to reduce the sources of directly weapons-usable material in the fuel cycle.

In October 1977, President Carter proposed that the United States accept limited quantities of foreign spent power reactor fuel for storage in the United States when such action advances our non-proliferation objectives. Legislation for this purpose was submitted to Congress in 1978, but by the end of December 1980 had not been acted on. In his February 1980 message to Congress on the management of nuclear wastes, the President reaffirmed this proposal and his support for the Administration's spent fuel storage legislation, which would, *inter alia*, provide for the storage of foreign spent fuel.

DOE continued to work during 1980 toward meeting the requirements of the National Environmental Policy Act and to continue studies and other work essential to implementing the President's offer to store foreign spent fuel, should the Congress pass the necessary implementing legislation. In May 1980, *The Final Environmental Impact Statement, U.S. Spent Fuel Storage Policy* was issued. It is a generic environmental impact statement covering both the offer to store foreign spent fuel and a domestic program of away-from-reactor spent fuel storage. Preparations to draft a programmatic EIS dealing with potential sites for AFR facilities are being made.

International Spent Fuel Management

During 1980, DOE continued to support U.S. participation in the International Spent Fuel Management (ISFM) study organized by the IAEA.⁵ Within ISFM, progress was made toward the preparation of a report on the technical and economic aspects of international cooperation in the storage of spent nuclear fuel. Countries participating in the study have also begun to examine the institutional, legal, and procedural aspects of such cooperation.

Pacific Basin Spent Fuel Storage

The Department of Energy has played the key role in providing technical input and support for a joint U.S.-Japanese feasibility study of the concepts of interim spent fuel storage on a Pacific island. Following informal consultations over a period of several months, the United States and Japan signed in July 1980 a minute of agreement to cooperate in such a study. In October, the two sides held a technical meeting in Tokyo to discuss a prospective work plan and assignment of tasks for the study.

On November 14, 1980, the U.S.-Japanese Pacific Basin Feasibility Study Steering Committee met in Washington to adopt a final work plan for the study and agreed that the study would be accomplished over a 2-year period beginning in January 1981. No decision to build such a facility is anticipated in the near future. A primary consideration in determining whether to proceed with the effort will be the results of thorough evaluations of health, safety, environmental, political, social, and cultural factors. The relevant committees of the Congress will be kept informed of further developments.

Views and Recommendations

The United States should continue to support international programs for cooperation in the storage of spent power reactor fuel. A number of studies, including those undertaken for INFCE, indicate that unless positive steps are taken there will be a serious worldwide shortage of spent fuel storage capacity.

The U.S. feels that spent fuel storage also can provide a more proliferation-resistant alternative for the back end of the fuel cycle than premature reprocessing. International programs, such as those described above, contribute to a greater international awareness of the problem, the sharing of advanced spent fuel storage technology, and the

creation of institutional and technical mechanisms for international cooperation.

Development of Proliferation-Resistant Fuel Cycle Technologies

Introduction

As part of its non-proliferation responsibilities, DOE has been examining a variety of fuel cycles and nuclear systems to determine if the proliferation risks of existing technologies might be reduced.

Reduction of Enrichment in Fuel for Research Reactors

In April 1977, the Administration decided to work toward minimizing the use and distribution of high-enriched uranium.⁶ One element in that policy is a program aimed at developing and encouraging the use of reduced-enrichment fuel in research reactors on a worldwide basis when such changes do not diminish reactor performance and do not affect safety standards. During 1979, a number of foreign manufacturers and possibly others participated in the fabrication of fuel and the development of the required technology.

Extensive cooperation between the U.S. and various foreign programs continued during 1980. International meetings to discuss the progress of low-enriched uranium fuel development⁷ were held periodically. As a result of a U.S. initiative, international technical expert teams and fellowships for personnel have been granted through the IAEA to those research reactor operators without sufficient capabilities to undertake independent conversion programs. In addition, arrangements are well under way to test prototype assemblies of reduced-enrichment fuel for a Triga reactor in the 14-megawatt-electric Triga research reactor in Romania. This activity is in support of the procurement assistance program announced by the United States at the 1978 United Nations General Assembly special session on disarmament.

The U.S. hosted a meeting to review progress of high density reduced-enrichment reactor fuel development for research reactors in November 1980. Papers presented at the meeting indicated that development of low-enriched uranium fuel is progressing very satisfactorily, and that countries that have the required facilities are conducting

⁶Uranium in which the percentage of the fissionable isotope U-235 has been increased to more than 20 percent by enrichment.

⁷Uranium containing less than 20 percent U-235.

⁵Background information on this study appears in the *Second Annual Report on Nuclear Non-Proliferation*.

vigorous development programs. Such countries have been very responsive to the U.S. reduced-enrichment initiative.

Views and Recommendations

General international acceptance of the use of lower-enriched fuels in research reactors in place of high-

enriched fuels would represent a major contribution to reducing the risk of proliferation associated with nuclear R&D. INFCE has endorsed the use of such fuels. Although a number of nations are taking steps to develop and use such fuels in their research reactors, the U.S. should continue programs designed to encourage the wider use of reduced-enrichment research reactor fuels.

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- U.S. Department of Energy. Office of Nuclear Affairs, International Nuclear and Technical Programs. *Analysis of Retransfer of Special Nuclear Material from Japan (Fukushima 1, 3, and 4) to the United Kingdom*. Washington, U.S. Department of Energy, August 28, 1980.
- U.S. Department of Energy. Office of Nuclear Affairs, International Nuclear and Technical Programs. *Analysis of Retransfer of Special Nuclear Materials from Japan (Fukushima 1, 2, and 5) to the United Kingdom*. Washington, U.S. Department of Energy, July 11, 1980.
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Chapter 16

Energy Contingency Planning

Introduction

The world petroleum market not only is in fragile balance, but also is subject to sharp changes in price and supply. The vicissitudes of world petroleum supply and demand are evident in the contrast between the domestic supply situation in 1979, when motorists waited in long gasoline lines, and 1980, when U.S. oil stocks and exploratory drilling both reached record levels and total petroleum imports decreased by about 20 percent from the 1979 average.

Until the United States reduces significantly its demand for foreign oil, the Nation will remain vulnerable to the exercise of market power by oil-exporting countries and vulnerable to sudden and protracted losses in supply.

As is emphasized in the Posture Statement and throughout this report, the United States now has a variety of major programs under way to increase energy self-sufficiency through expanded production and more efficient use of available supplies. But because of the long lead times for many of these programs, the United States will continue to be heavily dependent on uncertain foreign supplies for the next decade. Further, the Nation's allies are even more dependent than the United States on imported oil, and most of them do not have the domestic resources that would allow an assured transition away from reliance on petroleum imports.

It is therefore imperative that the United States—both independently and collectively with its allies—take actions to reduce the vulnerability brought on by import dependency. These actions include developing contingency response measures to increase oil supplies, to reduce de-

mand for oil, oil products, and oil substitutes, and to manage remaining supplies of oil and substitutable energy sources during a disruption. And they include improving the capability to plan these responses and coordinate them during an energy emergency.

Framework for Contingency Planning

The Secretary of Energy is the President's Energy Crisis Manager for the Federal Government. He is also the chairman of the Energy Coordinating Committee, a cabinet-level body which advises the President and helps coordinate policy formulation and decision-making pertaining to energy matters. During an energy supply interruption, the committee will review the assessments it receives of the domestic and international energy situation, recommend appropriate actions to the President and his other advisors, and coordinate implementation of the approved responses.

In April 1980, the Secretary established the Office of Energy Contingency Planning in the Economic Regulatory Administration to provide a focus for the development of contingency plans within the Department. This office is functioning as the core staff for the preparation of a set of coordinated contingency response plans that could be used to mitigate the effects of various emergency shortage conditions. The DOE program offices that have operational responsibility for particular measures included in the contingency plans are contributing to the planning process; these offices also will be responsible for program operation during energy emergencies. The response plans being developed will define specific steps to be taken to implement emergency measures and will provide for coordination

among Federal, state, and local governments, private industry, and individual consumers.

The initial task of the Office of Energy Contingency Planning was to prepare a draft contingency response plan for a hypothetical oil embargo. In connection with this effort, the office has prepared detailed implementation plans for a number of supply enhancement, supply management, and demand restraint measures that are available to the Federal Government for responding to an oil supply interruption. This initial plan will serve as the prototype for others to follow. Plans for other types of energy emergencies will be developed expeditiously.

The Energy Liaison Center was established to enhance the Department's lines of communications with state and local governments and DOE regional offices in the event of energy emergencies. The Center serves as the primary contact point between state energy offices and DOE, ensuring expeditious processing of requests for assistance and information about impending Federal actions. The Center also fosters an intergovernmental approach to short-term energy shortages through innovative measures such as the "Energy Emergency Handbook," which provides Federal, state, and local officials with practical, timely, and accurate information which they could use during energy emergencies. In addition, the Center has developed an extensive guidebook for states on the operation of the gasoline and middle distillate set-aside program, as well as a computer software package to assist them in their management of the program.

In conjunction with the Center, the Energy Information Administration is using the latest telecommunications and data processing technologies to develop the Energy Emergency Management Information System. This system will assemble and communicate information needed by decision-makers at the Federal, regional, and state levels during an emergency.¹ Aspects of the system facilitated the active participation of eight states in the October-November 1980 test of the International Energy Agency oil-sharing plan.

The Department's petroleum gathering and monitoring capability will be a critical element in preparing for and responding to an emergency. The current data gathering systems enable DOE to track the flow of crude oil from the source through the refinery and the distribution chain at the prime supplier level on a monthly and, in some cases, weekly basis. These systems will provide the information and data base needed to formulate recommendations to effectively manage emergency responses. The weekly reporting component now contains information based entirely on Government-collected data and is not dependent on information from industry trade associations.²

Two recent innovations in inventory data gathering have been developed by DOE. A monthly report that reflects prime supplier 3-month projections of crude oil and refined product stocks on an equity basis was initiated during 1979. The prime supplier 3-month projection of total supplies and stocks is collected irrespective of where those products are located in the flow. The Crude Oil Ownership Reporting System, which collects monthly equity-based data reflecting crude oil loadings, volumes in transit, and landings, was initiated in September 1980. The data are also collected irrespective of crude location in the flow. Information from both these systems would be used to assist the Department in monitoring industry stocks that might be required during an interruption to sustain the flow of product to the marketplace.

DOE is conducting a survey of approximately 6,700 industrial fuel-burning installations, by state and industry, that have dual fuel-use capability and use over 50 million Btu's per hour of energy. The report will identify which type of fuel is currently being used in each facility and will enhance DOE's capability to estimate emergency fuel switching potentials.

Outside DOE, the Federal Emergency Management Agency has overall Government responsibility to assist states, local governments, and individuals in planning for emergencies. The Agency will assist the Secretary of Energy, in his capacity as Crisis Manager, by performing a variety of support functions during an energy emergency to ensure effective coordination and implementation of decisions at both the Federal and state levels.

Centralized coordination and dissemination of key policy decisions and information can be facilitated through an Interagency Energy Coordinating Group, chaired by the Federal Emergency Management Agency, and similar groups at regional and state levels. Within the executive offices, authorities and personnel responsible for both planning and line operations during an energy emergency have been designated by Department Secretaries and other Agency heads.

The industrial sector represents the Nation's first line of response during any supply emergency, and DOE has asked representatives of energy-producing and energy-consuming industries to contribute to its efforts toward improving the Nation's emergency preparedness. Organizations with which DOE already has established a working relationship concerning contingency planning include: U.S. Chamber of Commerce; Electric Power Research Institute; National Electric Reliability Council; Edison Electric Institute; American Public Power Association; National Rural Electric Cooperative Association; American Gas Association; National Petroleum Council; National Association of Manufacturers; National Academy of Engineering; and the National Governors Association.

The Department has requested that these groups iden-

¹See Chapter 10 for further details.

²Ibid.

and articulate actions that could be taken voluntarily by various industries to restrain demand, increase supply, or use available supplies more efficiently. Further, they have been asked to consider carefully the complementary roles of private industry and government during emergencies and to propose a functionally efficient structure for effective management of energy emergencies. DOE has stressed the need to identify and eliminate institutional barriers that might jeopardize achieving this objective.

Enhanced Supply Actions

Large inventories of crude oil and petroleum products help reduce vulnerability in the short run. This protection can be achieved by expanding the Strategic Petroleum Reserve as well as by taking other measures to enhance supply, including encouraging private industry to build up fuel stocks above traditional levels.

Strategic Petroleum Reserve

The Energy Policy and Conservation Act of 1975 authorized the creation of a Strategic Petroleum Reserve of up to 1 billion barrels to diminish U.S. vulnerability to a severe petroleum supply interruption. A Strategic Petroleum Reserve Plan, detailing proposals to design, build, and fill the Reserve, was submitted to Congress in

February 1977 and became effective in April 1977. Implementation plans have been prepared for the first 750 million barrels of crude oil for storage. Decisions have not yet been made regarding the extent of Government and industry involvement in providing the final 250 million barrels of protection.

The Strategic Petroleum Reserve program is currently being developed in three distinct phases. Phase I consists of the development of 248 million barrels of existing storage capacity in five salt dome sites—one in Texas and four in Louisiana—and a marine terminal at St. James, Louisiana, on the Mississippi River (see Figure 16-1). The Phase I storage sites can be collectively filled at a rate of up to 500,000 barrels per day.

Phase II of the program consists of storage capacity expansion of the Bryan Mound site by 120 million barrels, the West Hackberry site by 160 million barrels, and the Bayou Choctaw site by acquiring an additional 10 million barrels. This 290-million-barrel capacity expansion will be accomplished by creating new storage caverns by means of solution mining (leaching). Construction of Phase II is under way, and leaching at Bryan Mound commenced in March 1980.

During 1980, development continued at the five storage sites and the marine terminal to implement Phases I and II. The storage sites and their planned capacities are

Figure 16-1—Strategic Petroleum Reserve System

shown in Table 16-1. These storage facilities, plus some 4 million barrels in interconnecting pipelines and surface tanks, will provide 538 million barrels of storage. Phase III of the program entails the creation of 212 million barrels of new storage space.

Through an interagency agreement, the Defense Fuel Supply Center contracts for Strategic Petroleum Reserve oil based on DOE specifications. The Energy Security Act of 1980 requires the President to acquire crude oil to expand the Strategic Petroleum Reserve at a rate of at least 100,000 barrels per day for 1981 and for each fiscal year thereafter. The act also requires that beginning October 1, 1980, oil from the Naval Petroleum Reserve (NPR) not be sold or disposed of except to fill the Strategic Petroleum Reserve—unless the Reserve has at least 500 million barrels of crude in storage, or unless the Reserve is being filled at an average rate of at least 100,000 barrels a day. The Department is carrying out these policies by implementing an oil acquisition strategy based on exchanges of oil from the NPR. (DOE plans for using Naval Petroleum Reserve oil in the Strategic Petroleum Reserve were completed before the Energy Security Act was signed into law.) The Strategic Petroleum Reserve resumed filling operations in September 1980. As of December 31, 1980, the amount of oil in storage and under U.S. title control was 107.8 million barrels, distributed as shown in Table 16-1.

Table 16-1—Planned capacities and end-of-year amounts in storage at Strategic Petroleum Reserve storage sites (Phases I and II)

<i>Strategic Petroleum Reserve storage sites</i>	<i>Planned capacities</i>	<i>Amount in storage December 31, 1980</i>
	(millions of barrels)	
Sulphur Mines		
Calcasieu Parish, Louisiana	22	0.007
Weeks Island		
Calcasieu Parish, Louisiana	75	4.579
West Hackberry		
Cameron Parish, Louisiana	211	37.998
Bryan Mound		
Brazoria County, Texas	180	38.364
Bayou Choctaw		
New Iberia Parish, Louisiana	46	25.187
Tanks/Pipelines	4	1.691
Total	538	107.826

The Strategic Petroleum Reserve sites have been designed and constructed to supply crude oil to interstate and local pipelines, and to tankers. The Strategic Petroleum Reserve is currently capable of distributing 1.7

million barrels per day through permanent drawdown systems installed at the five operating sites. The drawdown capability will increase to over 3 million barrels per day upon completion of Phase II of the program in 1987.

The Department conducted two highly successful exercises in 1980 to draw down crude oil from the Strategic Petroleum Reserve. On February 27, a spot drawdown test was called by the Secretary without warning. This required the movement by pipeline of 300,000 barrels of crude oil from the West Hackberry site in Louisiana to the Sunoco Terminal in Nederland, Texas, about 42 miles away. In April, an operational readiness exercise was conducted involving the simultaneous drawdown of approximately 1.4 million barrels of oil from the three Strategic Petroleum Reserve storage sites with crude oil inventory (Bryan Mound, Bayou Choctaw, and West Hackberry). This oil was shipped by pipeline to aboveground storage tanks in the St. James Terminal, the Bryan Mound site, and the Sunoco Terminal in Nederland.

The Department has completed an oil distribution plan which was approved by Congress in November 1979 as Amendment No. 3 to the Strategic Petroleum Reserve Plan. The Distribution Plan describes how the Reserve may be used to mitigate the effects of a severe supply interruption. The plan also sets forth methods to be used in selecting the recipients of Strategic Petroleum Reserve oil, the options for selling the crude oil, and the pricing of oil from the Reserve during a drawdown.

Other Supply-Enhancement Measures

During 1980, U.S. petroleum industry stocks of crude oil, gasoline, and several other petroleum products were significantly higher than they were during the corresponding periods of 1979 and 1978. Specifically, during the first 10 months of 1980, primary stocks of crude oil and petroleum products averaged more than 9 percent higher than the corresponding 1978 levels and almost 14 percent higher than the corresponding 1979 levels (see Figure 16-2). These high stock levels in the United States and other industrialized nations provide an important buffer that could cushion the harmful effects of a disruption. To ensure a continuation of this margin of protection, DOE is examining options to maintain, and perhaps increase, private stocks of crude oil and petroleum products.

Other actions could also temporarily increase petroleum supplies. For example, waiving regulations governing the lead content of gasoline or Clean Air Act standards governing the use of higher-sulfur fuel oil could each reduce our need for imported oil by at least 15,000 barrels per day. DOE is also studying possibilities for increased "surge" production from existing oil fields.

Figure 16-2—Stocks of crude oil and petroleum products—1979 and 1980—excluding stocks held in the Strategic Petroleum Reserve and including crude oil in transit to certain refineries. Average level and width of average range are based on 3 years of monthly data, January 1977 to December 1979. The seasonal pattern is based on 7 years of monthly data, January 1973 to December 1979.

Demand Restraint Actions

Higher petroleum product prices, resulting mainly from increased world crude oil prices, played an important role in curbing U.S. oil demand during 1980. Replacement cost pricing—balanced with equity considerations—is key to a sensible energy policy. It should guide our policies to reduce imports in the long term and our policies to cope with potential supply disruptions in the 1980's. Price controls on domestic crude oil are currently being phased out for this reason, and decontrol could be accelerated if necessary in an emergency. In addition, removal of product controls would allow petroleum to be allocated in response to market forces and avoid misallocation that could result in gasoline lines in some areas.

In addition to market forces, there are a number of programs that can effectively reduce demand for petroleum while keeping government intervention to a minimum.

Emergency Building Temperature Restrictions Program

Some 3 million commercial buildings, with 40 billion square feet of floor space, account for more than 9 percent of the Nation's end-use energy consumption. Previous operating practices have wasted a portion of the energy

used for heating and cooling these buildings, making them prime targets for conservation efforts.

In the spring of 1979, the President determined that a severe energy supply interruption was imminent with respect to imported crude oil and petroleum products. Under authority of the Energy Policy and Conservation Act of 1975 (and after Congress had approved a specific conservation plan aimed at the commercial building sector) the President put into effect, on July 16, 1979, the Emergency Building Temperature Restrictions. Buildings covered by the regulations are prohibited from using energy to cool lower than 78° F., to heat higher than 65° F., or to heat domestic hot water higher than 105° F. At the conclusion of the authorized 9-month period for this emergency program, the President extended it for another 9 months, until January 16, 1981. The President could extend this program again if necessary.

Preliminary estimates by Argonne National Laboratory show that, during the first 9 months, the Emergency Building Temperature Restrictions saved the energy equivalent of approximately 116 million barrels of oil, or 421,000 barrels per day. Total Federal costs were \$7.9 million. The total demand reduction (resulting from the program and other factors such as higher prices) provided an estimated balance-of-payments savings of more than \$1 billion. If the program continued at the same rate of sav-

ings until January 16, 1981, it probably saved a total of 232 million barrels of oil equivalent. Argonne concluded, "the overwhelming economic benefits of the program are clear."

On the basis of the early inspection data, Argonne estimated that 84 percent of the covered buildings inspected were in compliance. As a result of the program, temperature settings were found to differ markedly from what they had been prior to the program—an average of 3 degrees higher for cooling, 4 degrees lower for heating, and 5 degrees lower on water heaters and on space heaters during unoccupied periods. When buildings were unoccupied during the cooling season, virtually all air-conditioning systems were shut off; before temperature restrictions, approximately half of these systems were left operating during the unoccupied periods.

Testimony by building owners and operators at a public hearing suggested that they generally complied with the temperature restrictions program because it held down the rise in energy costs. Both their testimony and some 70,000 calls to a toll-free hotline confirmed that, by and large, employees and the public have accepted the restrictions and adjusted to them by dressing accordingly given that implementation of the program has been perceived as fair and that the emphasis has been on education rather than enforcement. Though it is labeled as an "emergency" measure because of statutory requirements, this program (or one like it) could be adopted as a practical permanent energy conservation measure.

Emergency Energy Conservation Program

In passing the Emergency Energy Conservation Act of 1979 (EECA), Congress provided the Federal Government with emergency authority to set up mechanisms to deal with energy shortages. The act provides that states and local political entities be given the first opportunity to develop and implement emergency conservation measures for meeting mandatory energy demand-reduction targets during shortages. If they fail to meet the targets, then the Federal Government would implement mandatory conservation measures aimed at meeting conservation targets. Congress also indicated that, if the Nation is to avoid rationing, the states and the Federal Government must effectively carry out such conservation programs.

The program has three essential elements:

1. It provides authority to the President to establish nationwide and state-by-state monthly emergency conservation targets for any fuels or energy sources that may be in short supply because of an energy supply interruption.
2. If that emergency situation occurs, the act also requires that the state governors submit state plans to

DOE, indicating how the states will meet the target set by the President.

3. It provides for a Standby Federal Emergency Energy Conservation Plan that can be implemented by the President in any state that is failing to meet its target.

After the seizure of the American Embassy in Tehran, and shortly after the passage of EECA on November 5, 1979, the occurrence of an energy supply interruption appeared likely, if not imminent. Accordingly, DOE announced a voluntary state gasoline targets program to allow for the development and testing of consumption-monitoring and target-setting methodologies and to encourage a reduction in 1980 gasoline consumption compared to 1979 consumption. This program has been carried out with the active cooperation of state officials.

The first goal of the targets program, to establish consumption-monitoring and target-setting methodologies for gasoline usage in the states, was largely met. The second, holding 1980 gasoline consumption to 7 million barrels per day or less, also was met.

DOE provides technical and programmatic assistance to the states to help enable them to enact emergency measures, and seeks funds to provide grants to the states for emergency planning purposes. Under provision of the continuing budget resolution approved by the Congress in lieu of 1981 appropriations, a program solicitation was published to effect the disbursement of approximately \$1.6 million in grants to the states and territories to support first phase efforts to develop state emergency conservation plans. At the same time, DOE is developing a rulemaking process for awarding second phase grants from 1981 appropriations as soon as these funds become available.

The Assistant Secretary for Conservation and Solar Energy has initiated a program of mutual DOE-state consultation aimed at establishing an ongoing emergency planning process. This program is designed to achieve a working partnership with the states to guarantee a swift, sure, and coordinated response to any national energy supply interruption for which the President has established emergency conservation targets. To this end, regional EECA program managers have been assigned to each state to provide technical assistance in designing and analyzing state plans.

The Standby Federal Emergency Energy Conservation Plan would set forth the measures that the President could implement within any state in case of an emergency. At the same time, the plan would help guide the states in developing State Emergency Conservation Plans required by the act. The Standby Federal Plan, containing nine proposed and interim final measures, was published in February 1980. The plan originally contained measures covering public information, employer-based commuter travel, in-

Increased enforcement of the 55-mile-per-hour speed limit, minimum and odd-even fuel purchases, compressed workweeks, vehicle use stickers, and recreational watercraft use restrictions. The watercraft measure was dropped, however, and there is considerable doubt as to whether the vehicle sticker and compressed workweek measures will be included.

Several nonemergency conservation programs could be accelerated and made more comprehensive should an emergency arise. These include the Low Cost/No Cost program, the Residential Insulation Assistance program, and a program conducted at the local level to assist individuals in reducing their home energy consumption.

Supply Management Actions

Fuel Management

In addition to actions for increasing supplies and reducing demand, a third category of emergency response actions includes those measures designed to manage a shortfall of imported petroleum. Among the most important fuel management actions are oil-to-gas switching in the industrial and electric utility sectors and electricity transfers designed to maximize the use of nonpetroleum-generated electricity. Assisting DOE in its fuel management planning are representatives of the Electric Power Research Institute, the National Electric Reliability Council, the Edison Electric Institute, the National Rural Electric Cooperative Association, and the American Public Power Administration.

Oil-to-Gas Switching: An estimated 470 billion cubic feet of domestic natural gas production is currently available for emergency use, primarily in intrastate markets. Other sources could also be used if needed, including increased imports and use of underground natural gas storage. Uncommitted and available natural gas could replace the distillate and residual fuel oil used by utilities and other industrial and commercial consumers to the extent that burners capable of burning gas are currently burning oil. Though there is no authority to directly mandate the use of natural gas during an oil emergency, voluntary oil-to-gas switching can be facilitated by issuing temporary Public Interest Exemptions under the Powerplant and Industrial Fuel Use Act of 1978. Under the Fuel Use Act, mandatory oil-to-gas switching in utility and major industrial boilers can be accomplished indirectly by prohibiting oil burning during a severe energy supply interruption.

Electricity Transfers: Major electric utility and power pools are already engaging in large-scale voluntary inter-regional transfers (primarily economy exchanges) that have the direct effect of displacing oil use. This displacement currently amounts to 200,000 to 300,000 barrels per

day depending on system operating conditions and economic considerations. Greater levels of voluntary transfers should evolve with increasing oil prices. In an emergency, the Government could further encourage, facilitate, or, if necessary, order the transfer of electricity from coal and hydro sources to utilities that are now dependent primarily on oil. Regional Electric Reliability Councils would be used to encourage voluntary energy transfers, and the Federal Power Act could be used to order specific emergency interconnections and energy transfers if voluntary arrangements prove insufficient.

Standby Gasoline Rationing Plan

In accordance with the Emergency Energy Conservation Act of 1979, the Department developed a Standby Gasoline Rationing Plan that could be used to distribute gasoline in the event of a 20-percent shortfall in gasoline and middle distillate supplies. The Standby Gasoline Rationing Plan regulations, describing the requirements under which a rationing system would be designed, were submitted to the Congress in June 1980 and became effective July 30, 1980. Under this plan, the available gasoline supply would be distributed through Government ration rights checks to individuals with registered vehicles, to businesses, and to priority users. These checks would later be exchanged for gasoline coupons which would be required for purchasing gasoline. The plan includes provisions for supplemental allotments for priority users and businesses, for the free trading of coupons, and for access to additional ration rights for hardship cases.

The Department estimated that it would cost \$103 million and take 12 to 15 months to preimplement the plan to the point where rationing could be implemented in 90 days if an emergency should occur. Immediately after the plan was approved, the Department began a series of activities so that full-scale preimplementation could commence as soon as 1981 funding was made available. These activities included: establishment of a Gasoline Rationing Preimplementation Project Office; preparation of detailed functional descriptions for each major component of the rationing system; selection of a systems integration contractor; completion of a preliminary project schedule; survey of state motor vehicle agencies to determine state information capacities and needs; and preliminary discussions with some 30 states.

In the Department's 1981 appropriation, \$50.1 million was provided for preimplementation of the Standby Gasoline Rationing Plan. Recognizing that the planned preimplementation could not be completed within 12 to 15 months at this level of funding, DOE modified its preimplementation strategy to ensure that a rationing system would be available as quickly as possible. The modifications will make it possible to develop and have ready as

scheduled a less automated gasoline rationing system under which coupons would be issued based on a self-application and proof system rather than on an automated vehicle registration file system and ration rights check system. In addition, the modified system would use coupons printed in 1974 for the initial quarter if rationing were implemented before additional funds were made available to print more secure, machine-processable coupons.

Plan development activities performed before November 1980 will provide the base upon which the automated system will be developed if additional funds are provided by Congress. Adding the automated features to the basic rationing plan will require another 9 to 12 months once additional funds are made available.

Emergency Standby Allocation and Price Control

At the beginning of last year, DOE put in place standby regulations that can be activated to allocate available crude oil and product supplies in the event of a shortage. These regulations will not enhance supply or reduce demand and if left in place for any length of time would distort the energy sector of the economy. However, they will help ensure that no firm or region of the country suffers unfairly during a period of reduced supplies.

Market Mechanisms

When developing any emergency measures, market forces should be harnessed as much as possible. Analyses undertaken by DOE and others have shown that a competitive market response without government involvement possibly could result in a lower adverse economic impact from an interruption than a price and allocation control plan. Accordingly, DOE is proceeding to develop strategies that rely more on market forces and less on regulation. Such strategies are appropriate for emergencies that are not so severe as to require economic mobilization.

The Department is analyzing a number of ways to use market mechanisms during a disruption, including, for example, a system of emergency product taxes and rebates as an alternative to gasoline coupon rationing and petroleum allocation and price controls. Under such a system, a standby excise tax could be put in place, or increased, at the outset of an interruption to reduce demand and help hold down world oil prices. Revenues would flow to the U.S. Government rather than to foreign and domestic producers. (The benefits of such a plan would be greatly enhanced if all oil-importing nations imposed such an emergency tax.) The revenues could be rebated to consumers to reduce the overall economic impact of the interruption. DOE also is exploring the advisability of an

emergency tariff on imports coupled with a rebate system to accomplish the same result.

A preliminary report by DOE and Department of the Treasury staff, analyzing several alternative mechanisms for allocating reduced supplies of oil during a disruption, has been transmitted to Congress. DOE plans to work closely with Congress in evaluating market systems such as these.

International Arrangements: IEA Emergency Oil Allocation System

The International Energy Agency (IEA) oil-sharing plan, originally designed in the aftermath of the 1973 Arab oil embargo, is updated and revised continually as conditions in the oil market change. The IEA has two sharing mechanisms:

1. An IEA-wide emergency allocation system that would be triggered by a 7-percent or greater disruption in available oil supplies measured against a base period (the previous four quarters minus the most recent quarter).
2. A selective allocation system for a particular member country, or countries, triggered by a 7-percent or greater disruption in that country's available supply measured against the base period.

In the general system, supplies are shared on the basis of allocation rights and obligations for each country which are calculated after each country has taken measures to restrain its demand for world oil and to draw down its proportionate share of IEA oil stocks. The selective system is simpler: countries other than the one experiencing supply difficulties prorate the supplies needed on the basis of their share of base period supply. The United States was a prime mover for the adoption of the selective system, which is designed to assist a country that is specifically targeted in a producers' embargo, as the United States was in 1973-74.

A modest cutback in oil supplies that is insufficient to trigger either the general or selective allocation system (such as the net 3-percent reduction in world oil supply by curtailment of Iranian production in 1979) may be handled as follows:

1. Close monitoring of IEA supply availability and supply and price trends in the world market.
2. Consultations among governments and between the Secretariat and individual oil companies, traders, and suppliers for assistance with incremental supplies when a particular member is experiencing a shortfall too modest to trigger either allocation system (this was the case, for example, with several countries in Northwest Europe in the spring of 1979).

The IEA emergency information system, activated in January 1979, is still in operation because the United States, the IEA Secretariat, and other countries believe the oil market can become turbulent rather quickly—as happened again in 1980 as a result of the Iran-Iraq war. Under this system, the IEA Secretariat receives data on production, imports, exports, inventories, and inventory changes from industry and governments on a monthly basis.

The IEA oil-sharing plan has been tested against hypothetical supply interruptions. If a 7-percent or greater shortfall for the group occurred as a result of events originating in the Middle East or elsewhere, and if the Governing Board acting by unanimity or by weighted majority (in which the United States has one-third of the weighted votes) so approved, the oil-sharing plan would be activated.

Under the plan, each member country would reduce oil consumption by 7 percent of its base period consumption, either by conservation, fuel switching, increased oil production, or inventory withdrawals. Each of these countries also would draw down its emergency reserves by an amount equal to the ratio of its emergency reserves to total IEA emergency reserves multiplied by the remaining IEA shortfall after countries have restrained demand. (Required emergency reserves are currently identified as 90 days of net oil imports of the previous calendar year and may include both commercial inventories and government-owned stocks.) Applied to base period consumption, these

two steps would establish a country's supply right. If a country's supply right is less than its available supply, it would be a net supplier under the plan; if its supply right is greater than its available supply, it would be a net receiver.

How much oil any one country received or gave up would depend entirely on the scenario and its impact on imports. Oil preferably would be shared through voluntary offers by companies, as coordinated by the IEA Secretariat, or, if necessary, through mandated supply orders from governments to companies under their jurisdictions.

The general system was tested for a third time in October and November 1980. The purpose of this latest test of the IEA sharing plan, like the earlier tests in October 1976 and April-May 1978, was to perform a dry-run of the allocation system. The emphasis in the 1980 test was to exercise the National Emergency Sharing Organization in each country and, in so doing, to encourage emergency planning and preparation of demand restraint measures in each country in the event of a live crisis.

Country reviews of demand restraint programs by the IEA in 1979-80 revealed serious planning shortcomings in some major IEA countries. In a followup exercise, DOE tested the mandatory domestic allocation program for crude oil and petroleum products. The scenario used for a hypothetical supply interruption presented a "retroactive creeping crisis" (similar to the Iranian shortfall of 1979) and expanded that type of shortfall into a crisis serious enough to trigger the IEA system.

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Chapter 17

Departmental Administration

Introduction

The Department performs a variety of central staff and field management functions in the course of conducting its energy, defense, and general science programs. The first section of this chapter describes the functions which comprise the management and support activities, and the second section provides a brief overview of DOE's major field activities and describes a series of initiatives designed to improve field operations and management.

Management and Support

The management and support functions can be grouped into four district efforts: management initiatives, efficiency improvements, technical support, and liaison and outreach activities.

Management Initiatives

Management: The Department undertook two major management initiatives in 1980: the implementation of a Planning, Programming, and Budgeting System and the development of a coordinated approach to improve internal financial management.

The Planning, Programming, and Budgeting System (PPBS) provides a formal management system for the formulation of programs and budgets and for the allocation of the Department's resources. During the planning phase, current policy objectives are reviewed to identify those policy issues that may lead to legislative, regulatory, and budgetary initiatives. The programming phase focuses on the definition of program objectives, the long-term means

necessary to achieve those objectives, and the determination of manpower and funding requirements for a 5-year period. The result is the Five-Year Energy Plan that incorporates programming decisions. During the budgetary phase, the first of the 5 program-years undergoes the detailed pricing and narrative justification necessary to formulate the DOE budget-year request to the Office of Management and Budget and, subsequently, to Congress.

The implementation of this management system—beginning in December 1979 with the issuance of draft policy, programming, and fiscal guidance—involved the participation of every major organizational entity within the Department. In March 1980, all assistant secretaries, office directors, and administrators submitted estimates of the resources that would be required to accomplish their program objectives from 1982 through 1986. Program requirements were then reviewed by the Assistant Secretary for Policy and Evaluation, the Chief Financial Officer, and the Under Secretary. Issues which required secretarial attention were developed in the form of decision papers for the Secretary's review. Approved program requirements were recorded in DOE's first Five-Year Energy Plan in June 1980.

Through the first year of implementing PPBS, the Department took important strides in developing a balanced, forward-looking, multiyear, decision-making process for allocating scarce budget resources; continued efforts in the years ahead are necessary to ensure that this systematic process for achieving departmental program objectives becomes firmly established.

A counterpart to the Planning, Programming, and Budgeting System is the Financial Management Improve-

ment Program which strives to enhance the Department's financial management functions. Accomplishments during 1980 included the development and issuance of definitive policy guidelines and procedures for the administrative control of funds within the Department, the development of a system to track compliance with audit report recommendations from the General Accounting Office, DOE's Inspector General, other Government agencies, field office auditors, and accounting firms, and the completion and approval by GAO of the Department's accounting principles and standards. The Department also instituted formal, comprehensive procedures designed to improve financial execution and analysis capabilities. Efforts to achieve unified and stringent financial controls and reporting procedures will continue through 1981.

Policy: The evolution of energy policy is shaped in part by dramatic events, in part by slower, more gradual changes in the physical, economic, and political environment, and in part by new insights into the nature and causes of energy problems and the potential effects of policy choices on the future. The critical nature of the Nation's energy problems and the necessarily political character of the policy process have resulted in partial, and frequently abrupt, policy changes. Despite these inherent problems, DOE made progress in 1980 by establishing the Planning, Programming, and Budgeting System. PPBS is an analytical framework in which to evolve and implement a more cohesive national energy policy.

Energy policy must be forward-looking to provide the analytical groundwork for future decisive action. In November 1980, the Department completed a major study, entitled *Reducing U.S. Oil Vulnerability: Energy Policy for the 1980's*, on the ways in which the United States might reduce its vulnerability to a disruption in oil imports. The study followed a year that saw the transfer of power in Iran, the Soviet occupation of Afghanistan, a doubling of world oil prices, and, most recently, the conflict between Iran and Iraq. It is an analytical assessment of potential further efforts to reduce vulnerability. As such, it summarizes current understanding of the energy problem and projects the likely energy supply and end-use consequences of current policies and programs. Also, it provides background information on what are certain to become major policy issues and provides an agenda for future analyses.

During 1980, the Department conducted policy analyses to support congressional consideration of the phasing out of price controls on domestic crude oil, the enactment of the Windfall Profit Tax Act, and the passage of the Energy Security Act (which created the United States Synthetic Fuels Corporation and provided a variety of other incentives for energy conservation and increased domestic energy production). Such measures should sub-

stantially reduce U.S. vulnerability to future disruptions of oil imports.

In addition to these near-term analytical efforts, the Department initiated during the year a new program of fundamental, longer-term policy studies. These studies are being undertaken by research institutions, selected in a competitive process, that will be unconstrained by proximity to present policy or existing contractual arrangements with DOE. Successful implementation of this program should provide better information and analysis on which to base future policy choices.

Efficiency Improvements

The Department is improving the efficiency of pricing and negotiation activities associated with procurement and financial assistance awards. Working with the Office of Federal Procurement Policy, the Department is developing a program to ensure understanding and execution of concepts in achieving fair and reasonable prices in procurement and financial assistance awards. The Department's profit and allowable cost policies also are being examined to determine how incentives might be incorporated to encourage private sector participation in meeting the Nation's energy needs.

Objectives for the planning and the early initiation of 1981 award actions were distributed to DOE managers and will be monitored to ensure that these objectives are met. The intent is that requirements will be more evenly distributed throughout the fiscal year, resulting in the more efficient use of resources. To improve the procurement skills of those who review or administer contracts, DOE provided training in the procurement process to more than 500 headquarters technical and administrative staff members.

Because DOE does not have a contract administration capability in or near most offsite contractor locations, the Department has relied increasingly on the expertise within other Government agencies through cross-servicing agreements. Such agreements have been negotiated with the Defense Logistics Agency, the Defense Contract Audit Agency, and the Office of Naval Research. Results have been encouraging. The establishment of a standard format for contract administration delegation letters to these other Government agencies has further enhanced DOE efficiency in processing requests for support.

During 1980, the Department significantly improved the systems that control, distribute, and track correspondence, reports, proposed regulations, and decision documents. Such systems ensure that the public, Congress, and the White House receive timely responses to inquiries and that official documents of the Secretary, Deputy Secretary, Under Secretary, and Chief Financial Officer are processed promptly.

In particular, functions performed by the Action Coordination and Tracking System were expanded to enhance the system's role in coordinating and tracking regulations, policy and program issue papers, and other documents that require review, approval, or acknowledgment by Department principals. To ensure that deadlines are met, the system also tracks information requirements mandated by such legislation as the Energy Security Act and the Wind Energy Systems Act.

Further improvements in the systems are expected in 1981, including the integration of word processing equipment into existing systems to provide automatic acknowledgment letters and responses to common inquiries, and new additions such as micrographics equipment and a graphics terminal that can display information on subject and volume trends in mail. Finally, computer programs in the Action Coordination and Tracking System will be examined thoroughly to identify areas that could further enhance the system's capability.

The Department's equal opportunity commitment includes developing and implementing equal employment opportunity and affirmative action programs and processing discrimination complaints. Also, the Department ensures that organizations receiving financial assistance under its federally assisted programs comply with appropriate laws and regulations.

During 1980, the Department completed its review of all applications for Federal assistance under the Schools and Hospitals and Public Buildings Grant Programs to determine civil rights compliance. Affirmative action program plans were developed and approved in conformance with new Office of Personnel Management and Equal Employment Opportunity Commission instructions. The Federal Women's Program conducted a training program for supervisors and employees on sexual harassment. A related employee survey will be used to develop appropriate training programs and procedural guidelines. Also, the Department resolved more than half of the discrimination complaints carried over from the previous year.

During 1981, the Department intends to implement transitional year affirmative action program plans, focusing on underrepresentation of minorities and women. The Department will also expand its capability for automatic processing of equal employment opportunity statistical information, and conduct a national conference on career and business opportunities for women in the energy field. Other plans include the establishment of a skills file on prospective Hispanic employees and establishment of a civil rights program in the 10 DOE regional offices.

Assisting in improving the Department's internal efficiency is the Office of Inspector General (IG). This office promotes efficiency and economy in DOE programs and operations by preventing or detecting instances of fraud and abuse. To carry out this responsibility, the IG con-

ducts audits, inspections, and investigations. Audits conducted in 1980 included reviews of entitlement exemptions for new refiners, aspects of the weatherization program, and costs related to the Strategic Petroleum Reserve. There also were audits of furniture management and inspections of the biomass and geothermal energy programs and nuclear weapons materials. IG also investigated such diverse matters as supplier practices at service stations and public access to classified reports.

Technical Support

Technical support is essential to accomplishing the Department's existing program and operational objectives, and to implementing new programs. The technical support staffs offer legal, procurement, and scientific and technical expertise to the regulatory, research, development and demonstration, and financial incentive programs conducted by DOE.

Legal Support: The Department's legal staff in 1980 provided support for the implementation of the decision in favor of the phased decontrol of petroleum prices and the promulgation of the standby gasoline rationing plan, provided the legal framework for filling the Strategic Petroleum Reserve, assisted in the promulgation of final regulations for the Fuel Use Act program, assisted in the development of final regulations establishing bidding systems for Outer Continental Shelf lease sales, and coordinated the preparation of the Department's *Final Report to the President on Oil Supply Shortages During 1979*.

In support of Department of Energy programs, the DOE legal staff assisted in the promulgation of rules for energy efficiency standards for major home appliances and the Residential Energy Conservation Service, resolved differences with states over cooperative agreements for clean-up of radioactively contaminated sites, and negotiated an agreement with the State of South Carolina regarding transportation of defense-related radioactive waste and spent nuclear fuel.

Major activities anticipated for 1981 include working with the Environmental Protection Agency (EPA) to develop pollution control guidelines for commercial-scale synthetic fuels projects. These guidelines, to be used by EPA and state permit authorities on an interim basis pending development of standards, are planned to be sufficiently flexible to permit plant operation with reasonable cost-effective environmental controls. The legal staff will assist in developing regulations governing interim energy performance standards for new commercial and residential buildings. The interim standards will undergo testing in new Federal building construction and in two private sector buildings before final standards are issued.

The Department will present its position during 1981 on the relation of nuclear waste storage and disposal issues

to nuclear powerplant licensing before the Nuclear Regulatory Commission. In this proceeding, initiated in response to a court decision, the Nuclear Regulatory Commission will reassess its position that safe disposal of radioactive waste from licensed facilities will be available when needed. As the lead agency in radioactive waste management, the Department will be an active participant, along with participants from other Federal agencies, states, and interest groups.

As part of DOE's regulatory compliance responsibilities, the Department during 1980 made 18 referrals to the Department of Justice for criminal investigations of violations of regulatory requirements such as miscertification of crude oil, fraud in the entitlements program, misdirection of allocated products, and pricing violations. Resolution by the Department of Justice resulted in fines of more than \$3 million and refunds of \$24 million, and the issuance of \$421 million in civil enforcement documents as a result of the ongoing investigation of misconduct by crude-oil resellers. The Temporary Emergency Court of Appeals upheld the Department's position in 12 out of 13 cases.

The Department's 1980 outlay activities in part focused on implementing the Department's financial incentive authorities in the area of synthetic fuels, particularly those established under the Energy Security Act. Notable accomplishments included promulgating regulations governing loan guarantees for alternative fuel demonstration projects, negotiating international cost-sharing agreements with Japan and West Germany to finance the demonstration project of the Solvent Refined Coal (SRC-II) process to convert coal into liquid fuel, and providing the legal framework for implementing feasibility studies and cooperative agreements to develop alternative fuels projects.

Procurement: During 1980, the Department increased its awards of grants and cooperative agreements ranging from the installation of solar collectors in residences to feasibility studies for commercialization of large-scale technologies. This increase was substantial in both the number of individual awards and the dollar amount of the transactions. Over 5,000 awards were made during the year, more than three times the number awarded in 1979. This increase is attributable to several factors: the implementation of the Institutional Buildings Grant Programs authorized by P.L. 95-619, the authorization of new financial assistance programs for alternative and synthetic fuels, and the implementation of the Federal Grant and Cooperative Agreement Act of 1977 (P.L. 95-224). Procurement contracting activity continued at a very high level throughout 1980 (see Appendix C).

With increased use of financial incentive agreements such as loans, loan guarantees, price support loans, and price guarantees, it became necessary for the Department

to develop expertise in the negotiation, execution, and administration of agreements for those program offices supporting specific technologies.

During 1981, while the Synthetic Fuels Corporation is being organized, the Department will have a major role in drafting and negotiating the financial transactions resulting from solicitations issued under the Energy Security Act and the Federal Nonnuclear Energy Research and Development Act.

During 1980, the Department also developed regulations governing the awarding and administration of grants and cooperative agreements. It also trained personnel, assisted program offices, and reviewed the performance of the offices administering grants and cooperative agreements. Financial assistance regulations will be further amended in 1981 to incorporate improvements and to reflect Government-wide changes in policies and procedures. As one of the Federal agencies supporting numerous grants and cooperative agreements, the Department will be a major participant in guideline development for future programs.

Scientific and Technical Information: The Department of Energy maintains a large scientific and technical information program to assist scientists, engineers, and administrators employed by the Department, its contractors, and Federal, state, municipal, university, and industrial organizations. A major objective of the program is to collect from DOE researchers and other available sources scientific and technical information for use by decision-makers, problem-solvers, and crisis managers.

Given the extent and diversity of the scientific and technical information programs in DOE, the Department during 1980 initiated steps to:

1. Coordinate DOE supported scientific and technical information programs, including those of contractors
2. Inaugurate a research, development, and analytic program to promote new information technologies and techniques, develop user-required data bases, employ useful data bases and networks outside DOE, and assess the effectiveness of all DOE scientific and technical information programs
3. Organize a program to enhance the management of information programs to achieve higher productivity, lower costs of information gathering, handling, and dissemination, and the elimination of duplication in services, products, and facilities

During 1981 the Department plans to improve coordination among in-house and contractor scientific and technical information program managers and conduct a policy review of the various DOE information programs, including those involving an international exchange of in-

ormation.

In 1982 and in subsequent years, the Department expects to review the quality and quantity of scientific and technical information gathered; train DOE scientists, engineers, research managers, and others to use modern information resources and machinery; determine the desirability of closer exchange programs with other Federal agencies; review all DOE scientific and technical information data bases for improvements; and make internal and external data bases and other information services more accessible to decision-makers.

A necessary focus for carrying out the Department's energy information needs is the centralized technical information program carried out at the Technical Information Center (TIC) in Oak Ridge, Tennessee. The Center's responsibilities are to plan, develop, and administer technical information programs and systems and to acquire, publish, store, announce, and distribute the technical information generated throughout the world that is relevant to DOE programs and activities.

TIC added 140,000 abstracted and indexed energy references to its data files during 1980, bringing the total number of items stored to approximately 1.3 million. These files, one of the world's largest sources of energy-related information, have been standardized and structured for easy access by DOE managers and contractors involved in research and development activities. Largest among the data bases maintained and updated during 1980 is the Energy Data Base (EDB), a worldwide bibliographic and abstract reference system of energy research, development, and demonstration reports, conferences, and journals.

In addition to creating and maintaining data bases, the Center received and processed more than 22,000 DOE research, development, and demonstration reports, and, under the Technical Information Management System, monitored more than 7,500 DOE contractors to ensure that research results were made available to the Department in accordance with contract requirements. Also, 6,000 research-in-progress items and descriptions of current DOE research projects were received, processed, and reported.

Comprehensive announcement publications, which are products of the data files, are issued regularly to provide coverage of major Department programs. These include *Energy Research Abstracts*, *Energy Abstracts for Policy Analysis*, *Current Energy Patents*, *Energy Conservation Update*, *Fossil Energy Update*, *Fusion Energy Update*, *Geothermal Energy Update*, and *Solar Energy Update*.

In 1980, the Energy Data Base became available to the public for the first time through the National Technical Information Service in Springfield, Virginia. Agreements were completed with several commercial on-line computer

search systems to make the EDB available to commerce, industry, and academia. Approximately 600,000 of the more than 1 million items in the EDB will be searchable on these commercial systems.

Last year the Technical Information Center distributed more than 6 million copies of scientific and technical reports and filled 450,000 requests for energy information to DOE offices, contractors, and other researchers. Over 12 million nontechnical publications were distributed to industry, universities, and the general public. Approximately 130 information and technology transfer publications such as *Energygrams*, *Industrial Energy Conservation* publications, and handbooks were prepared for these same audiences.

The Center's plans for 1981 will concentrate on increasing the comprehensiveness of the energy information files and smoothing the flow of information from development to dissemination. In addition to expanding the Energy Data Base, the Technical Information Center also will continue to encourage private sector use of DOE-funded project results. A new announcement journal, *Syn-fuels Update*, is planned for publication in 1981. TIC expects to increase its support of state and local information centers and the Energy Extension Service. Efforts to improve the flow of information from the beginning of a research project to its completion will continue, as will efforts to acquire information on foreign energy technology for distribution in the United States. In carrying out its central role, the Center will endeavor to improve communications with integrated contractor libraries and program-specific information centers to ensure that they remain integral parts of the DOE information system.

In 1982, upon completion of the above-mentioned comprehensive review of DOE's data base needs, TIC expects to add more than 160,000 bibliographic items to its EDB. The research-in-progress data base is expected to substantially expand in consequence of improvements to the contract authority file, the technical information management systems, and contractor reporting mechanisms. In addition, the present system of responding to public requests directly will be converted to a network of referral strategy, whereby the bulk of the inquiries will be distributed to state and local outreach centers.

Liaison and Outreach.

Important for the success of the Department's regulatory, research, development and demonstration, and financial incentive programs is the forging of good relations with state, local, tribal, and territorial governments, minorities, consumers, the general public, and Congress. Toward this end, the Department has established liaison and outreach programs in intergovernmental, minority, consumer, public, and legislative affairs.

DOE's intergovernmental affairs program manages a wide range of liaison and outreach activities designed to ensure the participation of state, local, regional, tribal, and territorial governments in formulating national energy policy. Much of the work being conducted is accomplished in the Department's 10 regional offices (locations are shown in Figure 17-1).

The regional offices serve as the representatives of the Secretary of Energy. The offices conduct DOE business with state and other governments, and they act as a conduit of public concern for the Department on policy matters. DOE has expanded the responsibilities of these regional offices by authorizing them to oversee and implement many of the Department's programs, including the Weatherization Assistance Program for low-income persons and the Schools and Hospitals and Public Buildings Grant Programs.

In 1981, the Department will continue to rely upon the regional representatives in broadening its efforts to help state, local, tribal, and territorial governments develop and manage their energy resources.

State and Local: During the past year, the Department strengthened its contacts with state governments through public interest groups such as the National Governor's Association and the National Conference of State Legislatures. It also continued to work closely with state

energy offices to enhance the energy management capability of both the executive and legislative branches of state governments. This year, DOE was instrumental in bringing about state government participation in several programs by, for example, consulting with officials while establishing state gasoline conservation targets.

DOE also established close working relations with local governments through its work with public interest groups such as the National League of Cities, the U.S. Conference of Mayors, the National Association of Counties, and the National Conference of Black Mayors. The Department formed a Local Government Energy Policy Advisory Committee, a task force comprised of representatives of local governments to advise the Secretary in this critical area. The Department also provided limited technical assistance to help local governments develop their energy management capabilities.

Indian Tribes: DOE is committed to helping American Indians develop their energy resources by expanding the base of information needed by Indian tribes to make energy decisions, assisting with feasibility analyses of tribal energy products, providing technical assistance to tribes, and addressing the educational needs of Indian people.

In 1980, the Department assumed the leading Federal role in developing energy resources on lands owned by American Indians and negotiated a major technical

Figure 17-1—U.S. DOE regional offices

assistance program for the Council of Energy Resource Tribes. DOE also established an Indian Energy Production Efficiency Program, available to all tribes, to provide grants for the development of renewable resources. To date, five grants totaling \$250,000 have been awarded for projects ranging from a small-scale solar greenhouse to a large-scale hydroelectric plant and a geothermal well.

Territorial Affairs: For the first time, the Department established a Territorial Affairs group to coordinate and manage comprehensive energy development plans for each of the insular areas. These plans include a survey of existing and potential resources, a projection of each area's needs through the year 2020, and an estimate of the specific steps required to decrease the territories' dependence on imported oil. After this evaluation is completed, the Department will help the territories develop and oversee programs to manage their energy resources in the most efficient manner. DOE also plans to simplify the procedures required for territories to receive energy grants.

Complementing the DOE efforts aimed at state, local, tribal, and territorial governmental participation are activities geared toward minority and consumer impact, education programs, and public awareness of conservation techniques.

Minority Impact: A Minority Business Enterprise Task Force was established in March 1980 to alert DOE managers to the need for increasing Departmental participation in the minority and disadvantaged business program. DOE's existing program was reviewed, and specific recommendations were made for immediate and long-range modifications. A goal of \$250 million in procurement contracts was set for 1980, about double the 1979 achievement. The Secretary stressed the importance of this program to each secretarial officer and to the managers of major DOE field installations. A task force met with members of each office and all of the major government-owned contractor-operated (GOCO) activities. Plans were program-specific, and they established reporting requirements to monitor progress towards the goal of \$250 million in procurement awards to disadvantaged businesses. Data through September 30, 1980, indicated awards exceeded the established goal in reaching approximately \$262 million. A goal of \$300 million has been set for 1981.

In another initiative to increase minority and disadvantaged business participation in DOE programs, \$15.8 million in settlement funds, consent orders, and agreements were deposited with 79 participating minority banks at the beginning of 1981 as part of the Federal Minority Bank Deposit program. The funds, administered *pro bono publico* by the Bank of America and Citibank, were placed in time deposit accounts bearing interest at the prevailing 18-month Treasury bill rate.

Under the National Energy Conservation Policy Act of 1978, the Department is mandated to conduct an ongoing research program to determine the effects of national energy programs on minorities. To date, DOE has awarded research grants totaling \$320,000 to five historically black universities to perform this research.

Under the Technology Commercialization Grant Program, the Department provides grants up to \$10,000 to minority firms for development and marketing of energy-related products and services. DOE also expects to begin providing loans to minority businesses to assist them in developing proposals for participation in the Department's research, development, and demonstration program during 1981.

Consumer Impact: A particularly useful outreach activity is the Department's publication of the newsletter *The Energy Consumer*. Originally a summary report of consumer information briefings with a circulation of 20,000, it has evolved into a resource/information guide for citizens and communities, with a national distribution of over 100,000. It describes individual, community, state, and Federal Government energy activities, provides a forum for citizen discussion of major energy issues, provides information on DOE policies and activities, and identifies state and Federal resources helpful to citizens in community-based energy projects.

In June 1980, DOE published the first edition of the *Consumer Energy Atlas*, a comprehensive, single-source reference guide designed to help consumers find answers to energy-related questions. The *Atlas* contains information needed to answer some of the most frequently asked energy-related questions, and lists key contacts in national, state, and local government agencies, Congress, energy-related membership organizations, and trade associations.

Responding to an increasing number of requests for information and technical assistance on production of alcohol fuels from individual farmers and farm communities, DOE established the first toll-free information hotlines, developed curriculum materials, and coordinated an alcohol fuels production training program in 40 community colleges located in 23 states.

In September 1979, the President issued an Executive order designed to improve citizen access to information and participation in Federal agencies by requiring agencies to develop or strengthen consumer-related activities. In response to this order, DOE published its consumer plan on June 9, 1980. A key provision of the DOE plan is the requirement that complementary plans be developed by the assistant secretaries and administrators of major program offices whose activities have potentially significant consumer impacts. The primary objective is to strengthen interaction between the program office and consumers. One area of recent concern has been assuring consumer protec-

tion and public participation in the implementation of the Residential Conservation Service (RCS) program. The Department has conducted a comprehensive analysis of the consumer protection provisions of each state plan and is preparing an updated RCS analysis.

As part of its activities under the Public Utility Regulatory Policies Act (PURPA), DOE supported the development and publication of materials to improve consumer understanding of the objectives, provisions, and issues involved; and supported technical assistance and training for consumers in state-level PURPA proceedings.

A major consumer fraud prevention project has been initiated in cooperation with the Consumer Protection Division of the National Association of Attorneys General and 70 Economic Crime Project Offices of the National District Attorneys Association. The project will monitor energy advertising claims and consumer complaints about home energy and gasoline saving devices and set up a clearinghouse of such information for prosecutors. Other activities will include the independent laboratory testing of energy-saving devices, a monthly newsletter on monitoring and testing results, making expert witnesses available in cases involving fraudulent products, and training sessions for prosecutors on successfully prosecuting consumer fraud cases.

Education Programs: The Department of Energy conducts a number of education programs related to energy conservation and supply. A major activity has been the Faculty Development Program, which sponsors workshops to assist high school, elementary, and community college teachers in developing teaching skills on energy topics. Approximately 18,000 teachers nationwide, who collectively reach an estimated 2.5 million students each year, have participated in these workshops since 1978.

The Department has developed energy course materials for classroom use. Over 1.3 million packets of *Project for an Energy-Enriched Curriculum* were distributed on request, making it the most widely used energy curriculum material in the country. Additionally, over 3.3 million teacher factsheets on energy and 1.1 million other pieces of printed educational material were distributed.

Working with the American Vocational Association in the Pacific Northwest, DOE is helping vocational education schools to design and conduct training and workshop programs on conservation and energy supply technologies, such as alcohol fuels, methane, passive solar, and weatherization techniques.

In the spring of 1980, the American Association of Community and Junior Colleges conducted a project called "Energy and the Way We Live: A National Issues Forum," with funding from DOE, the National Endowment for the Humanities, and private contributors. These

forums, conducted in more than 450 communities, provided citizens the opportunity to obtain information about and express their opinions on the issues surrounding the Nation's future energy policy.

A future education activity is "Streamline America," a multimedia high school assembly program. The program suggests ways students can participate in energy activities in their homes, schools, and communities. Follow-up lesson plans and suggested student activities for teachers also are provided. The program will be field tested in 20 schools nationwide for 2 months beginning in February 1981.

To assist students and consumers in making appliance purchasing decisions, DOE is funding the development of a series of booklets on buying and using appliances efficiently. These educational brochures will be available for use in school home economics classrooms and will be available for general distribution through appliance retailers.

The scope of the Department's education programs is greatly increased by regional office support of a variety of innovative energy education projects. Typical examples: a speaker program at Ft. Lewis College in Durango, Colorado, on the impacts of energy development; solar skills workshops for urban residents in Massachusetts; workshops on mobile home conservation and retrofit and low- and middle-income rural residents in Vermont; science teacher workshops and conservation materials development for colleges and universities in the state of Washington; training for community volunteers to conduct conservation workshops in New Mexico; and a consumer education project on utility ratemaking processes in Texas.

Conservation Information: A coordinated information campaign was conducted throughout 1980 to place major emphasis on the importance of energy conservation in reducing the Nation's reliance on imported oil. This was done through press briefings, public announcements, and the Department's biweekly *Energy Insider* (circulation 60,000); through the development and distribution of energy publications, such as *Tips for Energy Savers*; through films; through feature stories on radio and television news broadcasts; through exhibits; and through the placement of a large number of energy speakers by the Speakers Bureau.

There was a major public service campaign with two seasonally oriented phases. The first phase, prepared prior to the summer driving season and launched on April 29, was aimed at conserving gasoline. The Department of Transportation was the primary agency involved with DOE. The features of this phase of the campaign were driver awareness, driver education and training, and efforts to encourage ridesharing and vanpooling.

The second phase, launched on July 22 in advance of the fall and winter heating season, was aimed at residential energy conservation. DOE worked with the Department of Housing and Urban Development in this effort, which emphasized home weatherization. Greater involvement was sought from neighborhood and volunteer organizations, businesses, and trade associations in order to mobilize community action programs. Awards for conservation results were part of the program.

The campaign theme for both phases was "Keep It Up, America—Keep on Saving Energy," which was developed for the Department by the Advertising Council. The campaign relied heavily on public service announcements on radio and television, and advertisements in newspapers and magazines. These efforts were supported by publications, exhibits, and other public presentations in the drive for greater efficiency in energy use.

A central feature of the public service campaigns is to expand involvement in conservation efforts through cooperative programs with major companies and organizations like IBM, the National Transit Association, the Boy Scouts, Jaycees, and American Legion. In this regard, DOE loaned negatives of conservation publications to organizations that reproduce and distribute them in large numbers at their own expense. This has the twofold benefit of multiplying the effectiveness of the outreach effort and minimizing the cost to the Department.

Approximately 12 million people are expected to see the Department's public affairs exhibits in 1981 at the DOE American Museum of Science and Energy, at the Chicago Museum of Science and Industry, and through the traveling exhibit program. About 30 million pamphlets and posters will be distributed.

Legislative Affairs: Given the evolutionary development of energy policy in the United States and the complex nature of the process, communication with Congress in particular, with the Department's authorization and appropriation committees and subcommittees, as well as with the leadership of both the House and Senate, is crucial to the Department's day-to-day operations and long-term goals. The legislative affairs function in DOE coordinates activities between Congress and the Department involving congressional hearings, monitors and maintains records of legislation, bills, and resolutions relevant to DOE, and informs authorizing committees and the leadership of both Houses of all activities within the Department, including, for example, visits to states by high-level DOE officials.

The extensive interaction between the Department and Congress is evident in the number of congressional hearings at which DOE officials testified in the first and second sessions of the 96th Congress. During the first session, DOE officials testified at 383 hearings before 38 full committees and 93 subcommittees. In the second session, they

presented testimony at 255 hearings before 29 full committees and 62 subcommittees.

Significant legislative milestones during 1980, described elsewhere in the Report, can be briefly summarized.

1. The Energy Security Act established the Synthetic Fuels Corporation—the vehicle through which the synthetic fuels industry will be funded and launched. The Corporation will act as a banker to provide financial incentives in the form of loan guarantees for up to 75 percent of each project's cost; price guarantees; and loans for up to 75 percent of estimated cost for projects that have reached the commercialization stage. Congress authorized the first \$20 million of an estimated \$88 billion total for this 12-year program.
2. The Windfall Profit Tax Act is expected to bring revenues estimated at \$227.7 billion into the U.S. Treasury between 1980 and 1990. Some of these revenues will be earmarked for DOE's continuing research and development efforts. Most of the tax provisions will be levied against oil companies, whose profits have risen sharply due to decontrol of oil pricing.
3. The Department also developed the standby gasoline rationing plan, which was reviewed and in effect approved by Congress on July 30, 1980. The plan is an emergency standby measure to be implemented if oil supplies are reduced by 20 percent. This emergency measure is designed to minimize chaos at the gas pumps and elsewhere should future oil supplies be curtailed.

Field Activities

The Department has a varied and extensive field structure whose functions have been described throughout the report. This section provides a brief overview of DOE's major field activities.

Overview

The Department has a large investment in the physical plants in which its major field activities are conducted. By the end of 1980, DOE owned or controlled over 9,000 buildings having a replacement plant value of more than \$17 billion (in 1982 dollars). In addition, DOE is responsible for roads, railroad tracks, test areas, ecology preserves, heating plants, and electrical and mechanical utilities. These facilities play an essential role in the Department's ability to conduct its energy, general science, and defense programs in a timely and economical fashion.

Fifty-six separate field activities are shown in two tables. Table 17-1 lists the name, operator, and location of

Table 17-1—Research and development facilities

<i>Facility</i>	<i>Operator</i>	<i>Location</i>
<i>Multiprogram Laboratories</i>		
Ames Laboratory	Iowa State University	Ames, IA 50011
Argonne National Laboratory	University of California/Argonne Universities Assoc.	Argonne, IL 60439
Brookhaven National Laboratory	Associated Universities, Inc.	Upton, NY 11973
Hanford Engineering Development Laboratory	Westinghouse Hanford Company	Richland, WA 99352
Idaho National Engineering Laboratory	Exxon Nuclear Idaho, Inc. and EG&G Idaho, Inc.	Idaho Falls, ID 83401
Lawrence Berkeley Laboratory	University of California	Berkeley, CA 94720
Lawrence Livermore National Laboratory	University of California	Livermore, CA 94550
Los Alamos National Scientific Laboratory	University of California	Los Alamos, NM 87545
Oak Ridge National Laboratory	Nuclear Division of Union Carbide Corp.	Oak Ridge, TN 37630
Pacific Northwest Laboratory	Battelle Memorial Institute	Richland, WA 99352
Sandia National Laboratories	Western Electric Company	Albuquerque, NM 87115
Savannah River Laboratory	E.I. DuPont De Nemours & Co., Inc.	Aiken, SC 29801
Solar Energy Research Institute	Midwest Research Institute	Golden, CO 80401
<i>Program-Dedicated Facilities</i>		
Bartlesville Energy Technology Center	Federal	Bartlesville, OK 74003
Bates Linear Accelerator Facility	Massachusetts Institute of Technology	Middleton, MA 01949
Bettis Atomic Power Laboratory	Westinghouse Electric Corporation	West Mifflin, PA 15122
Carbondale Mining Technology Center	Federal	Carbondale, IL 62901
Center for Energy and Environment Research	University of Puerto Rico	San Juan, PR 00935
Comparative Animal Research Laboratory	University of Tennessee	Oak Ridge, TN 37830
Energy Technology Engineering Center	Rockwell International Corp.	Canoga Park, CA 91304
Environmental Measurements Laboratory	Federal	New York, NY 10014
Fermi National Accelerator Laboratory	University Research Association, Inc.	Batavia, IL 60510
Grand Forks Energy Technology Center	Federal	Grand Forks, ND 58202
Inhalation Toxicology Research Institute	Lovelace Biomedical and Environmental Research Institute	Albuquerque, NM 87115
Knolls Atomic Power Laboratory	General Electric Corporation	Schenectady, NY 12301
Laboratory for Energy-Related Health Research	University of California at Davis	Davis, CA 95616
Laboratory of Nuclear Medicine and Radiation Biology	University of California at Los Angeles	Los Angeles, CA 90024
Laboratory of Radiobiology	University of California at San Francisco	San Francisco, CA 94143
Laramie Energy Technology Center	Federal	Laramie, WY 82071
MSU-DOE Plant Research Laboratory	Michigan State University	East Lansing, MI 48824
Morgantown Energy Technology Center	Federal	Morgantown, WV 26505
New Brunswick Laboratory	Federal	Argonne, IL 60439
Notre Dame Radiation Laboratory	University of Notre Dame	Notre Dame, IN 45556
Oak Ridge Associated Universities	Oak Ridge Associated Universities	Oak Ridge, TN 37630
Pittsburgh Energy Technology Center	Federal	Pittsburgh, PA 15236
Pittsburgh Mining Technology Center	Federal	Pittsburgh, PA 15236
Princeton Plasma Physics Laboratory	Princeton University	Princeton, NJ 08540
Radiobiology Laboratory	University of Utah	Salt Lake City, UT 84112
Savannah River Ecology Laboratory	University of Georgia	Aiken, SC 29801
Stanford Linear Accelerator Center	Stanford University	Stanford, CA 94305
University of Rochester Biomedical Laboratory	University of Rochester	Rochester, NY 14642

the research and development facilities in two groups: multiprogram laboratories which serve two or more DOE programs; and program-dedicated facilities which serve single DOE programs. Among the 41 research and development facilities, 32 are GOCO. The Environmental Measurements Laboratory, the New Brunswick Laboratory, 5 fossil energy technology centers, and 2 mining centers are staffed with Federal employees.

In addition to the research and development facilities, DOE also has four Regional Solar Energy Centers established because of the decentralized nature of solar energy applications. The four regions and the center locations are: Northeast, Boston, Massachusetts; Mid-American, Minneapolis, Minnesota; Western, Portland, Oregon; and Southern, Atlanta, Georgia.

Table 17-2 lists the name, operating contractor, and

Table 17-2—Production and test facilities

Facility	Contractor	Location
<i>Uranium Enrichment</i>		
Oak Ridge Gaseous Diffusion Plant	Union Carbide Corporation	Oak Ridge, TN 37830
Paducah Gaseous Diffusion Plant	Union Carbide Corporation	Paducah, KY 42001
Portsmouth Gaseous Diffusion Plant	Goodyear Atomic Corporation	Piketon, OH 45661
<i>Defense Materials Production Facilities</i>		
Ashtabula Feed Materials Plant	Reactive Metals, Inc.	Ashtabula, OH 44004
Feed Materials Production Center	National Lead Co. of Ohio	Cincinnati, OH 45239
Hanford Production Operations	Rockwell Hanford Operations & United Nuclear Industries	Richland, WA 99352
Idaho Chemical Processing Plant	Allied Chemical Corporation	Idaho Falls, ID 83401
Savannah River Plant	E.I. DuPont De Nemours & Co.	Aiken, SC 28901
<i>Weapons Testing and Fabrication Complexes</i>		
Kansas City Plant	Bendix Corporation	Kansas City, MO 64141
Mound Facility	Monsanto Research Corporation	Miamisburg, OH 45342
Nevada Test Site	Reynolds Electrical and Engineering Co., Inc.	Las Vegas, NV 89114
Pantex Plant	Mason & Hangar-Silas Mason Co., Inc.	Amarillo, TX 79177
Pinellas Plant	General Electric Company	St. Petersburg, FL 33733
Rocky Flats	Rockwell International	Golden, CO 80401
Y-12 Plant	Nuclear Division of Union Carbide Corporation	Oak Ridge, TN 37830

location of the uranium enrichment, defense materials production, and weapons testing, and fabrication activities managed by DOE.

Over \$6.5 billion of DOE's 1980 budget resources were spent at these facilities which employed almost 120,000 contractor personnel and approximately 1,000 Federal workers. The work being conducted by GOCO field activities is managed by 3,700 Federal technical and administrative staff members at the eight operations offices shown in Table 17-3.

The operations offices and multiprogram labs are a critical component of the Department's overall approach to solving energy problems—both from a research and a management perspective. The laboratories generally perform work that requires unique skills and facilities, is part of a necessary core research capability, or is not within the capability or interest of university or industrial sectors. While their principal contributions are in basic scientific research technology base and energy supporting research, the laboratories also play an important role in conjunction with the Operations Offices in implementing the Department's policy of decentralized project management and program execution.

Under this policy, DOE Headquarters sets goals and objectives in accordance with national energy policy, conducts overall program planning and management, develops overall policy and criteria, and delegates technical direction and project management authority to the appropriate field location. The Operations Office is responsible for managing a project's resources and keeping head-

quarters informed of work status and significant problems. For example, day-to-day program execution of mirror fusion work is the joint responsibility of the San Francisco Operations Office and the Lawrence Livermore National Laboratory. Operations offices retain their principal function of overseeing and managing the operating contracts for all of the contractor-operated facilities under their jurisdiction.

Table 17-3—DOE Operations Offices

ALBUQUERQUE OPERATIONS OFFICE Albuquerque, New Mexico 87115
CHICAGO OPERATIONS AND REGIONAL OFFICE Argonne, Illinois 60439
IDAHO OPERATIONS OFFICE Idaho Falls, Idaho 83401
NEVADA OPERATIONS OFFICE Las Vegas, Nevada 89114
OAK RIDGE OPERATIONS OFFICE Oak Ridge, Tennessee 37830
RICHLAND OPERATIONS OFFICE Richland, Washington 99352
SAN FRANCISCO OPERATIONS OFFICE Oakland, California 94612
SAVANNAH RIVER OPERATIONS OFFICE Aiken, South Carolina 29801

Management Initiatives

To more effectively operate and maintain its large investment in facilities, the Department has continued to develop an institutional planning process and the In-House Energy Management program and has launched new initiatives in site development, maintenance management, and the construction of general purpose facilities.

Institutional Planning: To ensure the optimal use of its laboratories over the long term, the Department has an institutional planning process. This process determines the type and level of work that will be conducted at each laboratory so that long-range plans, budgets, and work schedules can be prepared and agreed upon between headquarters and the field.

Major activities for improving institutional planning in 1981 and 1982 will include the integration of institutional planning into the Planning, Programming, and Budgeting System; the preparation of definitive role statements for each multiprogram laboratory; the refinement of program-dedicated laboratory institutional planning; and the inclusion of long-range facilities and site development data in the institutional plan.

In-House Energy Management: The Department's energy research and development activities and defense production and test activities use approximately 14.4 million barrels of oil-equivalent annually, excluding energy required for uranium enrichment. To set the example for both the Federal and private sectors, the Department established an In-House Energy Management program to direct DOE's efforts to conserve energy in its offices, plants, laboratories, and other facilities. This is accomplished through energy conservation surveys, building retrofits, and central heating plant optimization and cogeneration projects, as well as employee awareness, ridesharing, driver training, and other conservation programs.

As of mid-1980, such programs have enabled the Department to reduce its energy consumption from 1979 levels by about 4 percent per square foot. Focusing on conservation of petroleum products reduced petroleum consumption by 33 percent during the last year.

Also during 1980, the Department invested \$23 million in retrofits to improve the energy efficiency of its facilities. When these retrofit projects are complete, they will reduce the Department's energy consumption by 410,000 barrels of oil-equivalent annually. Additionally, the Department began the optimization of two of its central heating plants now burning petroleum and natural gas. One will burn coal, and the other will use process waste heat as the prime energy source.

Other in-house energy conservation efforts, including employee awareness and ridesharing programs, have con-

tributed to energy savings both on and off the job. Form: ride-matching services for carpools and vanpools are available to over 50 percent of DOE and operating contractor personnel. Through transportation programs and a gasohol program, the Department reduced the gasoline portion of its petroleum consumption by 8 percent from 1979. During 1980, gasohol supplied 24 percent of the gasoline needed by the Department.

Site Development: To effectively manage future development at its sites, DOE has initiated a long-range facilities planning effort to provide a better match between near- and mid-range program needs and existing facilities and to assist headquarters program managers to better plan their long-range placement program workload.

Site operating contractors, in accordance with instructions from the operations offices, will prepare site development plans. These plans are updated annually and will contain an analysis of current site problems and plans for growth, a 5-year planning section where facility growth is tied to the institutional planning process, and a long-range assessment of the potential for future site development to aid in future placement of facilities.

For the next 5 to 10 years, development will be determined principally by the requirements of headquarters program managers. Longer-range plans will be directed toward developing the maximum capacity of the site which will be determined by the operating contractor and the field organization. When fully implemented, this process will create greater stability and discipline in the planning and placement of the Department's support and programmatic facilities.

DOE-Wide Facilities Maintenance Management: DOE currently is working on a Department-wide maintenance management policy that will establish consistent, mission-oriented maintenance policies at each DOE site. Effective maintenance management techniques are essential because DOE plants are rapidly aging (buildings and utilities now average 25 years of age) and program requirements are increasing demands on facilities. A 1978 study estimated that as much as \$600 million per year is required to maintain DOE's physical plants. Investments of lesser amounts serve only to shorten the life expectancy of scarce facilities and increase the potential for interfering with the achievement of program goals at each site. On the other hand, increased investments in facility maintenance reduce the amount of funds available for program workload. The goal of the maintenance management policy is to strike a balance between protecting the long-term investment in the Department's facilities and fostering maximum program accomplishment.

Headquarters will establish the minimum criteria for a maintenance management program. Field organizations will develop instructions for implementing this program to

sure that site operating contractors adhere to these minimum criteria. Oversight of this process by the field organization shall be through the establishment of annual reporting procedures for facilities management. Specific activities to be accomplished at each site include:

1. Development of a formal written maintenance management program at each site
2. Development of 12-month and longer-range work plans
3. Establishment of a formal work order system to ensure resources are used efficiently and to protect the Government from waste, fraud and error
4. Establishment of a preventive maintenance program
5. Performance of an annual inspection survey of real property facilities
6. Preparation of a formal facility maintenance and repair budget which relates maintenance needs to program and facility priorities

Multiprogram General Purpose Facilities: Historically, DOE has relied on specific program sponsors to provide for the real property requirements necessary to operate specific sites. During the past 10 years, as the Department's multiprogram laboratories expanded and the work became more diversified, the responsibility for site-wide services at the labs became less clearly defined. With the requirements that each program justify its expenditures, requests for scarce financial resources to support site-wide services not principally used by a specific program led to conflicts between the program's interest and

the site's interest. As a result, general purpose facilities have been neglected.

A survey conducted in 1980 indicated that \$2 billion of the total inventory of \$8 billion in general purpose facilities is in a deteriorated state. Sustaining deteriorated and unsuitable existing facilities requires progressively higher operating and maintenance expenditures, thus creating a cost-ineffective drain on program operating budgets. In addition, the reliability of utility services, which are critical to the conduct of research and development at the labs, surpasses normal acceptable risks of unscheduled interruptions in heating, cooling, and electricity.

To alleviate this situation, the Department established the Multiprogram General Purpose Facilities program. The goals of this program are to identify deficiencies, develop corrective measures, and rehabilitate or replace deficient facilities to ensure that ongoing research and development activity at the labs is not adversely affected by physical plant conditions. The basis of the program is the recognition that the systematic replacement and rehabilitation of aging facilities is a legitimate cost of doing business and that this problem must be addressed on a continuing basis for as long as the Department conducts major programs at the multiprogram laboratories.

Thirteen projects are under way in 1981 at eight different labs. Each has been undertaken in accordance with a long-range site development plan and includes requirements for energy conservation, minimum life-cycle costs, and DOE design criteria for construction.

Appendix A

Foreign Direct Investment in U.S. Energy Sources and Supplies for 1979

Introduction

Section 657, subpart (8) of the Department of Energy Organization Act (P.L. 95-91) requires the Secretary of Energy to report on the U.S. activities of foreign companies or persons that own or control U.S. energy sources and supplies. Specifically, section 657 requires that the Secretary of Energy will report to the President for transmittal to Congress:

to the extent practicable, a summary of activities in the United States by companies or persons which are foreign owned or controlled and which own or control United States energy sources and supplies, including the magnitude of annual foreign direct investment in the energy sector in the United States . . .

In response to this statutory mandate, this report is a summary of foreign direct investment in the domestic energy sector for 1979. Foreign direct investment is defined by the Bureau of Economic Analysis of the Department of Commerce as "the direct, indirect, or a combination of direct and indirect ownership of 10 percent or more of the voting stock of an incorporated U.S. business enterprise or the equivalent interest in an unincorporated U.S. business enterprise."¹ Throughout this report, the term "foreign direct investment" is used interchangeably with "foreign-owned" and "foreign-controlled."

¹The minimum percentage of direct ownership necessary for effective corporate control varies from company to company. The Department of Commerce has used the 10-percent criterion since 1962.

The data base which underlies the financial information presented in this report distinguishes only petroleum as an energy source.² Consequently, the primary focus of this report is on petroleum and natural gas. The last section of the report includes information on foreign investments and acquisitions in the United States for all energy sources.

The Petroleum and Natural Gas Industries

During 1979, foreign direct investment in U.S. petroleum was increased to \$9.9 billion from \$7.8 billion in 1978 (see Table A-1). This amount of foreign direct investment in petroleum was 18.9 percent of the total foreign direct investment in the United States in 1979. By comparison, U.S. direct investment in foreign petroleum was 21.6 percent of total U.S. direct investment abroad for 1979. Reflecting the importance of petroleum in 1979, foreign direct investment in U.S. petroleum was increased 27 percent; U.S. direct investment abroad in foreign petroleum was increased 19 percent.

Additions to foreign direct investment since 1975 show an evident pattern: the major source of the additions arises from reinvested earnings (see Table A-2). In 1979, \$1,615 million came from reinvested earnings, while \$526 million of the total additions came from equity and inter-company account capital inflows. For 1978 and 1979, the

²U.S., Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, August 1980.

Table A-1—Foreign direct investment (FDI) in petroleum and all U.S. industries and U.S. direct investment in foreign industries¹

Year	FDI in U.S. petroleum ²	Total FDI in U.S. ³	Percent petroleum of total	U.S. direct investment in foreign petroleum	Total U.S. direct investment abroad ⁴	Percent petroleum of total
(billions of dollars)						
1974	5.6	25.1	22.3	21.4	110.1	19.4
1975	6.2	27.6	22.4	25.9	124.0	20.8
1976	5.9	30.7	19.2	28.7	136.8	20.9
1977	6.5	34.5	18.8	31.4	149.8	20.9
1978	7.8	42.5	18.4	33.8	167.8	20.1
1979	9.9	52.3	18.9	41.6	192.6	21.6

¹Source: U.S., Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, "U.S. Direct Investment Abroad in 1978," August 1980 and "Foreign Direct Investment in the United States in 1979," August 1980.

²Petroleum industry—includes all phases of petroleum exploration, production, refining, transport, and marketing.

³The FDI position is the value of foreign parents' net equity in, and outstanding loans to, U.S. affiliates at yearend.

⁴The value of U.S. parents' net equity in and loans to foreign affiliates.

Table A-2—Additions to foreign direct investment in U.S. petroleum—1974-1979¹

Year	Total addition	Equity and intercompany account capital inflows	Reinvested earnings of incorporated affiliates	Valuation adjustments
(millions of dollars)				
1974	822	431	431	-40
1975	599	79	520	0
1976	-301	410	538	-1,240
1977	652	52	601	0
1978	1,312	308	1,004	0
1979	2,142	526	1,615	0

¹Source: U.S., Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, "Foreign Direct Investment in the United States in 1979," August 1980.

composition was approximately 76 percent reinvested earnings and 24 percent equity and intercompany account capital inflows.

The leading sources of foreign direct investment in U.S. petroleum for 1979 were U.S. affiliates or subsidiaries of foreign companies in Europe, holding its historical predominance, with 81.3 percent; the Netherlands, with 64.6 percent; Canada, with 9.5 percent; and Latin America, with 7.5 percent (an increase from 4.6 percent in 1978). The percentage of foreign direct investment accounted for by the Organization of Petroleum Exporting Countries (OPEC) is not significant. (See Tables A-3 and A-4.)

The ratio of reinvested earnings to earnings is termed the reinvestment ratio. This ratio measures the proportion of earnings retained by the foreign-owned affiliate and tends to be an approximate correlate of the rate at which assets are accumulated. The rate of return reported in Table A-5 is the ratio of earnings to the average of the beginning- and end-of-year direct investment. As shown in Table A-5, the reinvestment ratios since 1977 exhibit a positive association with the rates of return. That is, reinvestment rates tend to increase as the rates of return increase. The wide variability in the rates of return from 12.6 percent for Canada to 23.8 percent for Europe is striking, given the recent performance of the petroleum industry.

Table A-3—Foreign sources of direct investment in U.S. petroleum—1974-1979¹

	Percent of total		Percent of total		Percent of total		Percent of total		Percent of total		Percent of total	
	1974		1975		1976		1977		1978		1979	
(millions of dollars)												
All countries	5,614	100	6,213	100	5,901	100	6,573	100	7,762	100	9,903	100
Canada	547	9.7	596	9.5	679	11.5	710	10.8	734	9.9	937	9.5
Europe ²	4,714	83.9	5,478	88.1	4,985	84.4	5,523	84.0	6,569	84.0	8,053	81.3
European Economic Community ³	4,673	83.2	5,398	86.6	4,904	83.1	5,428	82.5	6,449	82.6	7,857	79.3
Netherlands	(D) ⁴	-	(D)	-	(D)	-	(D)	-	5,041	64.3	6,400	64.6
United Kingdom ..	1,502	26.7	(D)	-	601	10.1	86	7.3	492	6.1	228	2.3
Japan	44	0.78	(D)	-	38	0.64	48	0.73	(D)	-	128	1.3
Australia,	N.S. ⁵	-	N.S.	-	(D)	0.06	(D)	-	(D)	-	3	0.03
New Zealand, and South Africa												
Latin America	291	5.1	101	1.6	173	2.9	276	4.1	356	4.6	747	7.5
OPEC	35	0.62	-2	-	2	0.03	4	0.06	2	0.05	9	0.09

¹Source: U.S., Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, August 1980.

²Europe entry consists of the European Economic Community plus Sweden, Switzerland, and other Europe.

³The European Economic Community includes Belgium, Denmark, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, and the United Kingdom.

⁴(D)—suppressed to avoid disclosure of data of individual companies.

⁵N.S.—less than \$500,000.

Table A-4—OPEC direct investment in the United States—1975-1979¹

Year	1975	1976	1977	1978	1979
(millions of dollars)					
Petroleum	-2	2	4	2	9
Manufacturing	(D) ²	29	24	49	52
Trade	-5	-9	-8	2	-7
Finance	N.A. ³	N.A.	49	63	82
Insurance	4	4	4	1	1
Real Estate	N.A.	N.A.	182	241	266
Other	(D)	164	1	8	-2
Total	169	190	256	366	401

¹Source: U.S., Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, August 1980.

²(D)—suppressed to avoid disclosure of individual companies.

³N.A.—not available.

Table A-5—Foreign direct investment: reinvestment ratios and rates of return—1974-1979¹

	1974		1975		1976		1977		1978		1979	
	Reinvest- ment Ratio	Rate of Return	Reinvest- ment Ratio	Rate of Return	Reinvest- ment Ratio	Rate of Return	Reinvest- ment Ratio	Rate of Return	Reinvest- ment Ratio	Rate of Return	Reinvest- ment Ratio	Rate of Return
	(percent)											
All Areas	65.8	5.8	68.1	8.5	69.4	10.6	65.1	8.7	75.3	10.9	77.4	12.7
Manufacturing	72.5	9.4	75.0	6.8	70.4	7.9	53.1	6.8	69.3	7.4	75.5	8.1
Petroleum ..	74.6	11.2	73.2	12.1	67.5	13.2	72.1	13.4	77.4	17.3	82.1	22.7
Canada ...	70.0	(D) ²	61.7	10.0	(D)	(D)	25.8	8.7	(D)	10.2	67.0	12.6
Europe ³ ...	73.4	11.2	71.8	11.7	(D)	12.8	(D)	13.0	(D)	17.1	82.2	23.8
EEC ⁴	72.3	10.9	71.5	11.7	73.8	13.0	73.0	13.2	77.2	24.4	81.4	22.9
Japan	90.0	4.7	97.0	(D)	96.0	2.5	95.0	1.4	87.0	(D)	99.0	(D)

¹Source: U.S., Department of Commerce, *Survey of Current Business*, August issues for 1975-80.

²(D)—suppressed to avoid disclosure of data of individual companies.

³Europe consists of the EEC plus Sweden, Switzerland, and other Europe.

⁴EEC (European Economic Community) consists of Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, and the United Kingdom.

But, considering the variation in the rates of return for U.S. direct investment abroad from 16.4 percent to 307 percent, the foreign direct investment rates of return reflect some stability.³ Comparison of the 35-percent rate of return for U.S. direct investment abroad in petroleum to the 22.7-percent for foreign direct investment in U.S. petroleum in 1979, indicates that, in 1979, foreign direct investment in U.S. petroleum was apparently less profitable than U.S. investment abroad in petroleum.

Summary of Foreign Investment Activity in Petroleum

Reserves: During 1978—the last year for which data is available—the share of domestic end-of-the-year proven crude oil reserves reported by foreign-controlled firms increased to 19.7 percent from 17.2 percent in 1977. This increase came from net purchases, corrections, and revisions rather than from extensions or from new discoveries. No change occurred in the foreign-controlled share of end-of-the-year dry natural gas proven reserves because production in 1978 exceeded reserve additions by 73 million cubic feet, an amount insufficient to alter the reserve share.

³Rates of return for U.S. direct investment abroad were taken from Bureau of Economic Analysis, op. cit.

Table A-6 presents petroleum reserve data for the group of firms identified as being foreign-controlled.⁴

Oil and Gas Production: In 1979 the foreign-controlled shares of the domestic production of crude oil (including natural gas liquids) and natural gas increased, continuing a trend that started in 1976. Since 1976, the foreign-controlled share of crude oil production has almost doubled, while the share for natural gas has increased slightly. Nevertheless, the foreign-controlled shares of both crude oil and natural gas production are relatively small. Also, the total increase in the foreign-controlled crude oil share between 1978 and 1979 is principally accounted for by the increase in crude oil production by Standard Oil of Ohio. Table A-7 presents the domestic crude oil and natural gas production of identified foreign-controlled companies from 1976 to 1979.

Refining and Gasoline Marketing: Little change has occurred in the foreign-controlled shares of U.S. operating refineries or total crude oil throughput capacity since 1976.

⁴The Office of the Oil and Gas Information System, Energy Information Administration, collects reserve data on a gross ownership basis. That is, each ownership interest reports the gross reserves in which it has any ownership right. This reporting scheme may cause the over-reporting of actual proven reserves.

Table A-6—Proven petroleum reserves, production, and reserve change for identified foreign-controlled companies—1977-1978¹

Reserves, production, and reserve changes (Gross ownership basis)	1977		1978	
	Crude Oil ²	Dry Natural Gas ³	Crude Oil ²	Dry Natural Gas ³
End-of-previous-year proven reserves	5,619	15,274	5,507	15,736
Changes to proven reserves				
Net purchases, corrections, and revisions	37	44	1,009	35
Extensions and discoveries ..	77	1,073	46	775
Production	253	843	402	883
Net change during year	-139	274	653	-73
End-of-year proven reserves ⁴ ..	5,480	15,548	6,162	15,663
End-of-year proven reserves as a percent of U.S. total	17.2	7.5	19.7	7.5

¹Source: U.S., Department of Energy, Energy Information Administration, Office of the Oil and Gas Information System, "Form EIA-23." (Not all foreign-controlled companies submitted Form EIM-23. The companies omitted from this report constituted a relatively small percentage of total proven reserves.)

²Millions of barrels of 42 U.S. gallons.

³Billions of cubic feet, 14.73 psi, 60°F.

⁴May not sum, because of rounding.

Gasoline operations of foreign-controlled companies reflect changing domestic marketing conditions. Table A-8 presents data on the refinery operations of foreign-controlled companies. Table A-9 indicates that foreign-controlled companies, like all U.S. companies, have generally reduced the number of their branded stations. This decrease, however, has not significantly affected their share of gasoline sales, which has increased fractionally since 1976.

Sources of Foreign Direct Investment In U.S. Energy Markets During 1979

The information contained in this section was gathered from the Department of Commerce's Office of Foreign Investment in the United States. The information is from public sources.

Petroleum

Apache Corporation: Apache Corporation has signed a joint venture oil and natural gas exploration agreement

with Grace Petroleum Corporation. The agreement calls for Apache to operate the first five wells drilled within the next 2 years. Apache Corporation is based in Minneapolis, Minnesota. Thirty-one percent of Grace Petroleum Corporation is owned by the Flick Group of Dusseldorf, West Germany.

Asamera Oil Corporation, Ltd.: The Canadian corporation announced a \$24 million expansion of its Asamera Oil, Inc., (U.S.) oil refinery in Colorado.

Bonanza Oil & Gas, Ltd.: Bonanza Oil and Gas, a Canadian company, acquired the Sovereign Exploration Company of Texas for 1.6 million shares of Bonanza Oil & Gas Ltd.'s common stock. Sovereign is a producer of crude oil and natural gas.

Bowman Development Company, Ltd.: The company, based in Canada, has purchased oil leases in Ocean County, New Jersey. The purchase prices were not disclosed.

British Petroleum Company, Ltd.: British Petroleum is controlled by the Government of the United Kingdom. The company increased its equity interest in Standard Oil Company of Ohio (SOHIO) to 53.1 percent from 52.0 percent. This is the maximum share British Petroleum can acquire.

Canada Development Corporation: A Canadian oil and gas exploration firm, this corporation increased its equity interest in Texasgulf, Inc., to 32.9 percent from 30.7 percent. The value of the transaction was \$17.1 million. Canada Development Corporation is an agency of the Canadian Government.

C. Itoh & Company, Ltd., MAPCO, and Anglo Industries, Ltd.: The three companies have formed a partnership, the MAPCO-Anglo Industries-Itoh Partnership, to explore for oil and natural gas within concessions leased by the State of Texas. Itoh, a Japanese company, has a 12.5-percent share of the venture. MAPCO is an oil and natural gas exploration company.

Deminex-Deutsche Endolversorgung GmbH: Deminex acquired Creslenn Oil for an undisclosed amount. Creslenn produces 1,200 barrels of oil per day and about 902 million cubic feet of natural gas. Creslenn has a 15-percent interest in the Beatrice Field in the North Sea. Deminex is a joint venture of several German oil firms, including the West German Government-controlled VEBA AG of Dusseldorf.

Ente Nazionale Idrocarburi: Italy's state-owned producer, the Ente Nazionale Idrocarburi, through its U.S. affiliate AGIP Petroleum, has entered into a joint venture with Texaco, Inc., to explore for oil and natural gas in the United States. Texaco, as operator, will drill six exploratory wells on its lease holdings in Texas, Mississippi,

Table A-7—U.S. petroleum and natural gas production of identified foreign-controlled companies—1976-1979¹

Company	Net crude and natural gas liquids				Net Natural Gas			
	1976	1977	1978	1979	1976	1977	1978	1979
	(burels per day)				(millions of cubic feet)			
Shell Oil Co.	527,000	505,000	497,000	480,715	645,990 ²	648,970 ²	646,050 ²	634,544 ²
Standard Oil (Ohio) .	25,479	167,308	528,402	610,976	28,969	31,370	30,366	29,419
American Petrofina .	19,775	19,367	19,660	19,241	17,334	16,483	17,916	18,035
Husky Oil Co.	14,084	14,580	14,728	15,194	7,121	7,644	6,628	9,624
Total Petr. (NA) Ltd.	3,309	4,460	4,324	5,534	7,379 ³	9,318	8,505 ³	10,328 ³
W. R. Grace & Co. ⁴ .	8,789	9,822	10,967	10,647	22,620	26,437	28,725	32,332
Texas Gulf Inc. ⁴	630	636	644	1,063	14,905	18,686	15,906	15,000
Total of Above	599,066	721,173	1,075,725	1,143,190	744,318	758,908	754,096	749,282
Total for U.S.	9,735,000	9,863,000	10,268,000	10,180,000	19,952,000	20,025,000	19,636,000	19,670,000
Percent foreign of U.S. total	6.2	7.3	10.5	11.2	3.7	3.8	3.8	3.8

¹Source: U.S., Department of Energy, Energy Information Administration, *Annual Report to Congress 1979*, and Company 10-K reports to the Securities and Exchange Commission.

²Previously reported on wet hydrocarbon basis.

³Natural gas sales.

⁴Not previously reported.

and Pennsylvania. AGIP Petroleum will earn an interest in the leases through its financial participation.

Mitsubishi Corporation: A Japanese trading company, Mitsubishi Corporation acquired a 20-percent interest in Fletcher Oil & Refining Company of Carson, California, for \$10 million. Fletcher had 1977 sales of \$95 million.

Panjea Corporation and San Jacinto Exploration, Ltd.: These two Canadian oil exploration companies have acquired oil leases for 150,000 acres in southeastern Arizona. The leases are valued at \$1.5 million. The companies agreed to drill 15 exploratory wells on the property during 1979.

Piper Petroleums, Ltd.: A Canadian crude oil and natural gas producer, Piper Petroleums acquired the Beasley Oilfield interests of Chapman Oil Company of Houston, Texas, for an undisclosed amount.

PREMO Petroleum, Inc.: A Dallas, Texas, subsidiary of Premier Consolidated Oilfields, Ltd., of London, England, PREMO Petroleum acquired 50 percent interest

in 356,000 acres of oil exploration concessions in the Rocky Mountain states for \$2.2 million.

Royal Dutch/Shell Group and Belridge Oil Company: The two have signed a definite merger agreement. Shell will pay \$3.7 billion in the largest takeover in U.S. corporate history. The merger has been challenged in court by both Mobil Oil Company and Texaco which own 17.9 percent and 17.0 percent of Belridge Oil, respectively. Belridge Oil is based in Los Angeles, California.

Standard Oil Company of Ohio (SOHIO): This company acquired part of the Beaufort Sea Oil leases in Beaufort, Alaska, for \$70 million. SOHIO is an integrated oil company. British Petroleum Company, Ltd., which is controlled by the Government of the United Kingdom, owns 53.1 percent of SOHIO.

Also, the Standard Oil Company of Ohio announced the acquisition of Newco Exploration Company and Webb Resources, Inc., for \$97.1 million in stock. Newco and Webb are oil and natural gas exploration companies. The

Table A-8—U.S. refinery operations of identified foreign-controlled companies—1976-1979¹

Company	Operating Refineries				Total Crude Oil Throughput Capacity			
	1976	1977	1978	1979	1976	1977	1978	1979
	(barrels per day)							
Shell Oil Co.	8	8	8	8	1,148,000	1,137,000	1,136,000	1,136,000
Standard Oil (Ohio)	3	3	3	3	449,000	452,000	452,000	452,000
American Petrofina	3	1	1	2	161,000	110,000	90,000	150,000
Husky Oil Co.	3	3	3	3	57,400	59,400	60,000	60,000
Total Petr. (NA) Ltd.	1	1	2	2	41,000	40,000	82,500	82,800 ²
Fletcher Oil & Refining	NF ³	NF	NF	1	NF	NF	NF	26,000
Total of Above	18	16	17	18	1,856,400	1,798,400	1,820,500	1,906,800
Total for U.S.	273	290	301	318	16,398,372	17,047,724	17,440,885	17,988,121
Percent foreign of U.S. total	6.5	5.5	5.6	5.7	11.3	10.5	10.4	10.6

¹Sources: Company annual reports, 1976-1979, and DOE/EIA-0111 (1979 & 1980) *Energy Data Reports*, "Petroleum Refineries Annual."

²Based on 1978 capacity plus additions to 1979 on stream day basis. Calendar day capacity not reported in 1979.

³NF—not foreign-controlled during this period.

Newco acquisition is contingent upon the successful completion of the Webb acquisition.

Coal

Cane Company, Ltd., Inc.: Cane Company, based in the Bahamas, has acquired 10,000 acres of land north of Chattanooga, Tennessee, containing substantial proven reserves of coal. The value of the acquisition is \$5.2 million. Cane Company has leased the land back to Eastern Mineral Corporation for 12 years with renewal options. Eastern plans to deep mine the coal reserves.

Gulf Oil Company: Gulf Oil Company and the Governments of the United States, Japan, and West Germany have agreed to the funding for a \$1.4 billion Solvent Refined Coal II process plant in West Virginia. The United States will provide \$600 million, Japan and West Germany \$700 million, and Gulf Oil Company \$100 million.

USACO, Inc.: A Kentucky corporation formed by a group of German investors, USACO has purchased 2,000 acres of coal land in Letcher County, Kentucky, for \$10 million. The corporation plans to open a mine and build a mining-processing-loading facility to be operative in August 1980.

Eventually, USACO plans¹ to construct coal liquefaction and gasification plants in Letcher County. Horst Schierach is the head of the group of investors.

Uranium

Total Group Societe and Pechinery Ugin Kuhlmann: Through their subsidiary, Menatome Company of Denver, Colorado, Total Group Societe and Pechinery Ugin Kuhlmann purchased leases on property belonging to several Georgia landowners and have begun preliminary drilling for uranium samples. Total Group Societe is a subsidiary of Cie. Francaise des Petroles (CFP), an oil exploration company, in which the Government of France holds 40 percent of the voting rights.

Urangesellschaft USA, Inc.: The Denver-based subsidiary of Urangesellschaft mbH & Company KG of West Germany, Urangesellschaft USA has been prospecting for uranium in south-central Vermont and signed leases with Vermont landowners.

Solar

Sensor Technology, Inc.: The corporation, based in Chatsworth, California, has joined with two French sub-

Table A-9—U.S. gasoline sales of identified foreign-controlled companies—1976-1979¹

Company	Total Branded Service Stations				Gasoline Sales ²			
	1976	1977	1978	1979	1976	1977	1978	1979
	(millions of gallons)							
Shell Oil Co.	19,656 (11.2) ⁴	18,418 (10.2)	16,985 (10.2)	16,559 (10.8)	'	'	'	'
Standard Oil (Ohio)	4,906 (2.8)	4,522 (2.5)	4,109 (2.5)	4,361 (2.9)	'	'	'	'
American Petrofina	5,758 (3.3)	3,597 (2.0)	3,498 (2.1)	3,315 (2.2)	'	'	'	'
Husky Oil Co.	573 (0.3)	NA ³	547 (0.3)	497 (0.3)	'	'	'	'
Total Petroleum	NA	365 (0.2)	732 (0.4)	965 (0.6)	'	'	'	'
Fletcher Oil & Refining ...	NF ⁶	NF	NF	0	NF	NF	NF	'
Foreign Total	NA	NA	25,872 (15.5)	25,697 (16.4)	13,953 (13.0)	14,429 (13.1)	15,587 (13.7)	14,841 (13.8)
U.S. Total ⁷	175,228	181,063	167,249	152,678	106,973	110,023	113,616	107,770

¹Sources: *National Petroleum News* (Fact Book Issue), 1976, 1977, 1978, 1979; EIA Form P-302, *Monthly Report for Refined Product Prices*; DOD/EIA-0066 *Petroleum Market Shares*, "Report on Sales of Retail Gasoline," July issues 1977, 1978, 1979, 1980; DOE/EIA-0035, *Monthly Energy Review*, October 1980.

²Gasoline sales refers to total gasoline sales.

³Disaggregated company numbers are considered proprietary by the U.S. Department of Energy.

⁴Numbers in parentheses are percentages of the U.S. total.

⁵NA—not available.

⁶NF—not foreign-controlled during this period.

⁷U.S. total gasoline sales represents total U.S. gasoline supply, as reported in the *Monthly Energy Review*.

sidiaries of Cie. Generale d'Electricite to produce solar energy photovoltaic modules in the United States. Dyer Corporation of Westport, Connecticut, the parent com-

pany of Sensor Technology, is 35.5 percent owned by Basel Trading Co., Ltd., of Switzerland.

Appendix B

Exports of Energy Resources by Foreign Companies

Introduction

Appendix B addresses "exports of energy resources from the United States by foreign-owned or controlled business entities or persons and such other related matters as the Secretary may deem appropriate." In conjunction with Appendix A, which covers foreign direct investment in United States energy sources and supplies in 1979, this report meets the reporting requirement of section 657, subpart (8), of the DOE Organization Act.

The direct export of U.S. energy resources by foreign-owned companies is not significant. U.S. laws and regulations impose licensing requirements which rigorously control the export of crude oil, refined products, natural gas, and uranium by all firms.

There are no foreign-owned or foreign-controlled companies engaged now in the export of natural gas and uranium. Several companies identified with foreign interests are involved in the limited export of refined oil products. Under existing export reporting requirements, it is impossible to determine to what extent brokers involved in the export of U.S. coal represent foreign entities.

The Export of Crude Oil and Refined Oil Products

Identification of Exporters

Total exports of energy-related products to foreign entities (areas outside the United States and its territories) by foreign-owned companies operating in the United

States are minimal, amounting to less than 60,000 barrels per day or approximately four-tenths of 1 percent of daily U.S. consumption of petroleum. Exports of energy-related refined products by foreign-owned companies operating in the United States are even less significant, comprising only a small fraction of U.S. exports of refined petroleum.¹

Export Controls

All exports of crude oil and energy-related refined petroleum products are controlled by the U.S. Department of Commerce. Authority for such control is derived from four sources: (1) The Export Administration Act of 1979; (2) section 103 of the Energy Policy and Conservation Act; (3) section 201(11) of the Naval Petroleum Reserves Production Act of 1976; and (4) section 28 of the Mineral Leasing Act of 1920, as amended. The export from the United States of crude oil is prohibited without a validated export license from the Office of Export Administration of the U.S. Department of Commerce. Commerce Department regulations provide that, with the exception of foreign policy or national security considerations, licenses will be issued only when it is established that such export is consistent with the national interest and the purposes of the Energy Policy and Conservation Act and meets other rigorous tests.

¹The names of such companies cannot be included in this report as the information is regarded as proprietary data under the terms by which the information was collected by the Office of Export Administration, Department of Commerce.

Exports of energy-related refined petroleum products are also prohibited without a license. Quotas have been established for the controlled refined products, and licenses are generally issued only to the extent of the exporter's historic share of the overall quota for a particular product. Crude oil and refined products exports are dominated by U.S. companies, and in turn these exports are a small proportion of U.S. production.

Crude Oil

No U.S. crude oil is exported on a net basis. However, approximately 130,000 barrels per day, less than 1 percent of U.S. consumption, are now exchanged for equal quantities of Canadian crude as part of the Canadian/Domestic Crude Oil Exchange program. This supports the viability of several U.S. northern tier state refiners. Since these exchanges minimize acquisition costs on both sides of the border through improved efficiency of transportation, they are mutually beneficial.

Refined Products

The majority of U.S. exports of refined petroleum products are nonenergy products such as greases, carbon black feedstock oils, lubes, and petroleum coke. U.S. exports of energy-related refined petroleum products in 1980 were minimal, amounting to about 60,000 barrels per day or less than four-tenths of 1 percent of U.S. daily consumption. Exports of residual fuel and propane/butane mix oil represented a major part of this total. Exports of refined petroleum products by foreign-owned companies operating in the United States were even less significant, making up only a small fraction of the 60,000 barrels per day of energy-related products which were exported.

The Export of Natural Gas

Identification of Exporters

To the best of DOE's knowledge, the companies exporting gas are U.S.-owned. With the exception of Phillips Petroleum and Marathon Oil Company, the companies that are exporting gas are gas transmission and/or distribution companies with limited energy resource production capacity.

As shown in Table B-1, the United States exported approximately 56 billion cubic feet of natural gas in 1979. Approximately 90 percent of the exports consisted of deliveries of liquefied natural gas (LNG) from the Phillips Petroleum and Marathon Oil Company's Kenai, Alaska, LNG plant to Japan. The remaining exports consisted of

Table B-1—U.S. natural gas exports¹

	1979	1980
	(billion cubic feet)	
Canada	0.076	N.A. ²
Mexico	4.308	N.A.
Japan	51.289	N.A.
	55.673	45 ³

¹Source: Energy Information Administration

²N.A.—not available

³The 1980 figure is for actual exports for the first 9 months of the year. Approximately 90 percent of the exports are LNG deliveries from Kenai, Alaska, to Japan.

overland pipeline deliveries to Canadian (76 million cubic feet) and Mexican (4.3 billion cubic feet) border communities that are remote from their indigenous gas transmission systems. Moreover, the quantities exported were small in comparison to actual U.S. gas imports from Canada (1 trillion cubic feet in 1979) and prospective supplies from Mexico.

During the first 9 months of 1980, the United States exported 45 billion cubic feet of gas. LNG shipments from Alaska to Japan are expected to account for 90 percent of the exports. For the year, exports are likely to match 1979 shipments of 56 billion cubic feet.

Natural gas exports amount to well under 1 percent of total 1979 U.S. gas consumption of 20.2 trillion cubic feet. Further, the overland pipeline exports to Canada and Mexico involve border sales which maximize the economics of the logistical arrangements, while the LNG sales to Japan result in part from the fact that there are no LNG receiving terminals on the U.S. west coast.

Export Controls

The Department of Energy Organization Act vests in the Secretary, or his delegate, the legal authority to regulate imports and exports of gas. Section 402(f) of the act specifically reserves to the Secretary all authority (including section 3 of the Natural Gas Act) to regulate imports and exports of gas. Section 402(a)(c)(f) vests in the Federal Energy Regulatory Commission (FERC) most of the remainder of the authority formerly exercised by the Federal Power Commission.

In response to Government and industry concerns about the potential legal and policy problems arising from

the possible overlap of jurisdiction between the Secretary and FERC, the Secretary issued Delegation Orders 0204-25 and 0204-26 (October 18, 1978). In these orders the Secretary delegated different aspects of his import and export authority to the Administrator for the Energy Regulatory Administration and to FERC.

The delegation to the Administrator of ERA (0204-25) allows him to determine whether a proposed export of natural gas is not inconsistent with the public interest standards of section 3 of the Natural Gas Act. This determination would be based upon a number of considerations which may include: (1) the proposed price charged at the point of exportation; (2) consistency with DOE regulations or statements of policy specifically applicable to imports or exports of natural gas; (3) the national need for the gas proposed to be exported; and (4) such other matters within the scope of section 3 of the Natural Gas Act as the Administrator finds appropriate.

The delegation to FERC (0204-26) grants it the authority to exercise all functions under section 3 of the Natural Gas Act that have not been delegated to the Administrator and that have not been previously exercised by him in addition to the functions under sections 4, 5, and 7 of the Natural Gas Act. Reserved to FERC under the DOE Act is the authority to approve or disapprove applications for the siting, construction, and operation of particular natural gas export facilities while the Administrator has the authority to promulgate regulations or develop statements or policy governing such cases with respect to national energy policy considerations. FERC is also responsible for the continuing supervision of export projects through the ongoing review of energy company export tariffs.

Export of Coal

Identification of Exporters

The identification of coal exports by a producing company or mine is not available to DOE since transac-

tions are generally controlled by independent coal brokers. Most export coal is for metallurgical requirements and is a blend of coals from a number of suppliers with individual constituents varying by shipment. Statistical reporting information available at this time does not permit identification of the coal brokers or coal exporters of record by national origin. However, it appears that companies exporting coal are U.S.-owned coal/energy corporations. DOE has no authority to regulate or control coal exports.

Export of Uranium

Identification of Exporters

Eleven U.S.-owned companies exported 3,100 tons of uranium oxide in 1979. Six U.S.-owned companies contracted to export 1,800 tons of uranium oxide in 1980. The names of the exporters cannot be identified in this report because such information is regarded as proprietary under the terms by which export data are collected by the Department of Energy's Assistant Secretary for Resource Applications.

Export Controls

The export of uranium from domestic sources is controlled under the Atomic Energy Act of 1954, as amended, and under the Nuclear Non-Proliferation Act of 1978. The licensing of uranium exporters is controlled by the Nuclear Energy Regulatory Commission. In essence, exporters are granted licenses only if they maintain a U.S. business address and office, and can certify a legitimate energy need for the uranium.

There is no specific distinction between foreign and domestic corporations for purposes of issuing export licenses; however, the destination of exports is clearly stated. The principal recipients of U.S. uranium in 1979 were Japan, West Germany, Taiwan, Belgium, Sweden, and South Korea.

Appendix C

Major Recipients of DOE Funding

Tables C-1 and C-2 are summaries of the Department of Energy's contract funding and financial assistance activities during 1980.

Table C-1—Procurement and financial assistance in 1980¹

Total number of prime award actions to the private sector including awards to state and local governments where contract value was greater than \$10,000 and for which there were 1980 obligations	10,662	Total number of prime award actions to universities where contract value was greater than \$10,000 and for which there were 1980 obligations	1,656
Total dollars awarded to the private sector, including awards to state and local governments	\$9,474,012,084	Total dollars awarded to universities	\$1,345,019,498
Total dollars awarded to small business, including awards by GOCO contractors	\$1,527,127,331	Total number of financial assistance awards	10,312
Total dollars awarded to minority business, including awards by GOCO contractors	\$ 199,973,840	Total dollar amount for financial assistance actions	\$ 689,596,685
Total number of accepted unsolicited proposals from all sources	1,112	Total number of prime contracts administered	28,859
Total dollar amount for accepted unsolicited proposals	\$ 282,652	Total number of contractors doing business with DOE (had 1980 obligations)	11,494
		Total number of universities doing business with DOE (had 1980 obligations)	243

¹Preliminary dollar amount subject to continuous updating.

Table C-2—Contractors awarded \$10 million or more during 1980
(dollars in thousands)

<i>Contractor</i>	<i>Total year obligations¹</i>	<i>Contractor</i>	<i>Total year obligations¹</i>
University of California	\$902,482	Eagle-Pitcher	\$31,268
Union Carbide	683,624	TRW, Inc.	30,705
Sandia	559,883	Dravo Utility Construction, Inc.	29,530
Westinghouse Electric	485,524	National Lead	26,450
E.I. Dupont	388,148	Holmes and Narver, Inc.	26,336
Bendix Corporation	294,564	Welsh Drilling	26,281
Tennessee Valley Authority	292,700	Martin Marietta	24,835
AUA; University of Chicago	282,529	Bradbury and Stemm Construction	24,741
Ohio Valley Electric Co.	264,348	Monsanto	23,934
EG&G	262,650	Burns and Roe	23,346
Rockwell International Corp.	242,290	Alcoa	23,236
General Electric Co.	237,494	Global Marine Development	20,328
Associated Universities	202,521	Memphis Light & Gas	19,263
United Nuclear Industries, Inc.	167,370	Townsend and Bottom, Inc.	18,331
Rust Engineering Corp.	156,895	Institute of Gas Technology	18,060
Reynolds Electric and Engineering	153,142	Mardi	17,315
Resource Sciences	121,294	Alexander Grant and Co.	16,921
Battelle Memorial Institute	119,120	Fluor Engineering	16,863
University Research Association	104,057	RMI	15,434
Goodyear Corp.	89,712	Boeing	15,387
Princeton University	80,873	Iowa State University-Ames	15,124
Babcock and Wilcox Co.	76,965	Allied General Nuclear Services	13,548
Pittsburgh and Midway Coal	71,527	Mason and Hanger-Silas Mason	13,244
Stanford University	67,311	Science Applications	13,104
General Atomic Co.	62,443	M-K National	12,951
Exxon	60,961	Stearns Roger	12,878
Electric Energy, Inc.	60,311	Klein Construction	12,639
Catalytic, Inc.	55,556	Oak Ridge Associated Universities	12,372
Ashland Oil Co.	50,750	University of Rochester	12,371
Parsons Gilbane	49,708	Universal Oil Products	11,972
Massachusetts Institute of Technology	49,547	AVCO Everett Research Laboratories	11,914
Technadril	45,612	Illinois Coal Gas Group	11,545
Bituminous Coal Research	39,965	National Academy of Sciences	11,298
International Coal	36,690	University of Tennessee	11,095
Western Solar Utility	35,360	IBM	10,681
McDonnell Douglas	33,609	Combustion Engineering	10,571
Garrett Corp.	33,601	Ralph M. Parsons	10,539
Fenix and Scisson, Inc.	32,816	Computer Sciences Company	10,476
Bechtel Corp.	32,324	Aerospace Corp.	10,055
Swinerton and Walberg	32,207	J.A. Jones	10,000

¹Preliminary dollar amount subject to continuous updating.

Appendix D

Report on DOE Actions Taken Regarding Disclosure of Energy Assets by DOE Employees

Introduction

Section 603(a) of the Department of Energy Organization Act (henceforth referred to throughout the text of this appendix as "the Act") requires the disclosure by Department employees of energy assets within 30 days after commencing service with the Department and annually thereafter. (See full text of Title VI of the Act, Attachment I, for this and following references to sections of the Act.) Section 603(b)(2) provides that a report "with respect to such disclosures and the actions taken in regard thereto during the preceding calendar year" be included in the annual report made in conformance to section 657 of the Act.

This is the report for calendar year 1980. This report covers not only disclosures and other actions taken pursuant to section 603, but also certain activities pursuant to other sections of Title VI of the Act.

Section 603

In implementing section 603 of the Act during calendar year 1980, the Department made a general request to employees for submission of financial interest reports (DOE Form 3735.1) to fulfill the annual filing requirement. In addition to the submittals made in response to

this request, such reports have been submitted by new employees of the Department upon their entry on duty, and by departing employees upon termination of service.

Section 603 requires all employees of the Department—except those holding positions at or below Grade GS-12 of the General Schedule which have been determined to be of a nonregulatory and nonpolicymaking nature—to file these financial interest reports. In accordance with section 603(c) of the Act, the Department published a notice in the *Federal Register* identifying specific positions and classes of positions that meet these criteria and are therefore exempted from the disclosure requirements of section 603(a). (44 F.R. 24710-24764, April 26, 1979.)

Other Sections of the Act

In accordance with section 601(c)(1) of the Act, in March 1978 the Department prepared and published a list of entities determined to be energy concerns. The list was made available to employees by memorandum and includes approximately 22,900 names of persons, businesses, companies, corporations, and other entities engaged in energy-related activities as described in section 601(b) of the Act. Nearly all were selected through use of Standard

Industrial Classification (SIC) numbers, as published in the *Standard Industrial Classification Manual*, 1972, prepared by the Statistical Policy Division, Executive Office of the President, Office of Management and Budget.

Employees were cautioned that the energy concern list should not be considered all-inclusive: the list is reviewed continually. The Assistant General Counsel for Standards of Conduct assists DOE employees with any questions regarding the energy concern status of any particular firm.

Section 602(a) of the Act prohibits "supervisory employees", as defined in section 601(a) of the Act, from accepting any compensation from any energy concern; from holding any official relationship with any energy concern; from holding stocks or bonds of any energy concern; and from having any pecuniary interest therein. As a result of the review of financial interest reports submitted by supervisory employees during 1980, several employees were directed to divest themselves of energy concern holdings.

Section 602(c) of the Act provides that where exceptional hardship would result or where the interest is a pension, insurance, or other similarly vested interest, the divestiture requirements of section 602(a) may be waived by the Secretary of Energy for such period as he may prescribe. The Secretary has granted several such waivers.

Section 604 of the Act requires supervisory employees of the Department to file a report identifying energy concerns from which they have received compensation in excess of \$2,500 in any of the previous 5 years. New employees filling positions classified as supervisory employee positions, as well as current employees being promoted into such positions, are requested to submit this report (Form DOE-460).

Section 605 of the Act establishes restrictions on post-employment activities of former supervisory employees. The Department regularly provides advice to departing employees regarding these restrictions (and the post-employment restrictions contained in the Ethics in Government Act of 1978) and the requirement in subsection (b)(1) that former supervisory employees file reports of employment with energy concerns on May 15 of the first and second years following termination of Department employment.

The waiver of restrictions on the post-employment activities of former supervisory employees who have outstanding scientific and technological applications is provided for by section 605 when the national interest would be served. During calendar year 1980 several such waivers were granted.

Section 606 of the Act limits participation by supervisory employees in matters involving former employers that are energy concerns. Waiver of these limitations is allowed where the application of the limitation would work an exceptional hardship on the employee or would be contrary to the national interest. No waivers were granted in calendar year 1980.

Section 607 of the Act provides that reports submitted pursuant to Title VI shall be available to the public. The Department's policy is to release copies of reports to individuals upon request. During 1980 no requests were received for copies of such reports submitted by DOE employees.

Section 608 of the Act establishes civil and criminal penalties for violation of the reporting and other requirements of Title VI. No actions have been taken by the Department pursuant to this authority.

Appendix E

Financial Assistance Programs

Introduction

The Department of Energy continued to experience an increase in its statutory authority for financial assistance programs and in the funding of those programs—most notable, the Energy Security Act (P.L. 96-294), which was signed by the President on June 30, 1980.

During 1980, the Department either had or received statutory authority for the following programs:

1. Loan Guarantee Agreements
 - Geothermal
 - Underground Coal Mines
 - Electric and Hybrid Vehicles
 - Alternative Fuels
 - Municipal (Urban) Waste
 - Alcohol Fuels
2. Direct Loans
 - Small Scale Hydroelectric
 - Municipal Waste
 - Geothermal
3. Price Supports
 - Alternative Fuels
 - Municipal Waste
 - Alcohol Fuels
4. Purchase Agreements and Commitments
 - Alternative Fuels
 - Alcohol Fuels

5. Grants

Weatherization Assistance

University and Other Institutional Buildings

6. Cooperative Agreements

Program regulations have been issued covering all of the above programs.

Appendix E outlines DOE's existing financial assistance authority and describes the significant elements of current program development.

Program Development

Alternative and Synthetic Fuels Program

The Department of Energy Act of 1978—Civilian Application (P.L. 95-238, section 207) amends the Federal Nonnuclear Energy Research and Development Act of 1974 (P.L. 93-577) to authorize the Department of Energy to financially support alternative fuels demonstration facilities. These amendments (section 19 of the 1974 act) require the Department to report to Congress annually on the opportunities and alternatives for implementing an alternative fuels financial assistance program and to report on DOE's specific program plans and recommendations.

Specifically, the section 19 amendments authorize DOE to:

1. Provide loan guarantees for financing the construction and startup costs of demonstration facilities

converting domestic coal, oil shale, biomass, and other domestic resources into alternative fuels

2. Enter into cooperative agreements to share the estimated design, construction, operating, and maintenance costs of modular facilities converting oil shale into alternative fuels
3. Provide community impact assistance in the form of grants, loan guarantees, and direct loans to support planning and community development efforts in areas affected by demonstration facilities
4. Provide loan guarantees for financing the construction and startup costs of demonstration facilities generating desirable forms of energy, including synthetic fuels from municipal or industrial wastes, sewage sludge, or other municipal organic wastes
5. Provide interest differential assistance on taxable obligations, guaranteed by DOE, which are issued by governments that would otherwise issue tax-exempt obligations for financing municipal or industrial waste demonstration facilities

Under the first phase of the Alternative Fuels program, the Department selected 110 projects for funding support through feasibility study grants and project development cooperative agreements. The awards totaled \$178 million. On August 1, 1980, two additional solicitations were issued for feasibility grants and project development cooperative agreements leading to the future construction and operation of commercial-scale alternative fuels production facilities. A total of \$300 million was available under these solicitations.

In one of the first major results of this activity, on July 18, 1980, DOE entered into a conditional loan guarantee commitment of \$250 million with Great Plains Gasification Associates to assist in the financing of the first year's construction costs for a 125 million cubic foot per day high-Btu coal gasification facility located in Mercer County, North Dakota. Great Plains Gasification Associates has requested a loan guarantee in the amount of \$1.4 billion from the Department for this project.

The Office of Resource Applications issued two solicitations for financial assistance applications on October 15, 1980. One solicitation used the authority of the Federal Nonnuclear Energy Research and Development Act of 1974, as funded by P.L. 96-126, to award up to \$3.0 billion in price guarantees, purchase commitments, and loan guarantees to provide incentives for the construction of a commercial-scale synthetic fuels facility. The other solicited application for assistance under the Defense Production Act, as amended by the Energy Security Act and funded by P.L. 96-304, makes available up to \$3.0 billion in purchase commitments, advance payments against purchase commitments, and loan guarantees to applicants providing fuels for defense needs. Under both solicita-

tions, projects funded by DOE may be adopted by the U.S. Synthetic Fuels Corporation, and applications not selected for award may be considered for award by the Corporation, thus accelerating the Corporation's efforts.

Municipal Waste, Biomass, and the Alcohol Fuels Programs

The Energy Security Act (P.L. 96-294) contains Title II, the Biomass Energy and Alcohol Fuels Act of 1980, which, among other things, authorizes the Department of Energy to provide various forms of financial assistance to alcohol fuels, biomass energy, and municipal waste energy projects to reduce the dependence of the United States on imported petroleum and natural gas. A notice in the August 14, 1980, issue of the *Federal Register* set forth as a proposal the rules under which DOE will provide loan guarantees to assist such projects. The notice requested public comments on such a proposal; established dates for public hearings on the proposed rule; and requested persons to file voluntary applications for loan guarantees prior to promulgation of the final rule.

DOE published a final regulation for the Municipal Waste Reprocessing Demonstration Facilities program on May 13, 1980. This regulation sets forth guidelines for providing financial incentives for the construction, the startup, and the related costs for facilities demonstrating the conversion of municipal wastes into synthetic fuels, and for the generation of desirable forms of energy, including synthetic fuels, from municipal wastes in an environmentally acceptable manner. No awards have been issued under this regulation.

Other Programs

To date, DOE has executed four loan guarantee agreements for the Geothermal program and two loan guarantee agreements for the Electric and Hybrid Vehicles program. In addition, one conditional commitment for a loan guarantee agreement has been issued for the Underground Coal Mines program and one additional commitment for the Alternative Fuels program. A total of 43 direct loans have been issued under the Small Scale Hydroelectric program through 1980. No price guarantees or purchase agreements and commitments were executed during 1980.

Grants and Cooperative Agreements

As the Nation—through the Department of Energy—searches for alternative sources of energy and seeks to conserve available resources, grants and cooperative agreements have served as the stimulus for matching nationally defined needs to those of the non-Federal sectors. The

ious departmental initiatives that are funded by grant or cooperative agreements span the spectrum from installation of solar collectors in residences to feasibility studies of commercialization of large-scale technologies.

During 1980, the Department experienced a major increase in the use of grants (both entitlement and discretionary) and cooperative agreements. This increase was substantial both in terms of numbers of individual awards and the dollar amount of the transactions. In 1980, the number of such awards was in excess of 5,000—more than a threefold increase over 1979. The increases are attributable, in part, to the implementation of the Institutional Conservation programs (authorized by P.L. 95-619). The increase also comes from new programs, such as Alternative and Synthetic Fuels which have authorized the provision of assistance, and from the Department's implementation of the Federal Grant and Cooperative Agreement Act of 1977 (P.L. 95-224). These trends are likely to result in additional use of these instruments in the future.

Resource Allocation

With the Department's increase in the use of financial incentives agreements—such as loans, loan guarantees, price supports, and guaranteed market agreements—the Procurement and Assistance Management Directorate established the Office of Financial Incentives to assist program offices in awarding such assistance agreements. The

Office of Financial Incentives is responsible for the negotiation, execution, and administration of these agreements in conjunction with the program office responsible for the specific technology being supported by the Department.

The increased use of grants and cooperative agreements by the Department has resulted in the need to systematize the approach in this area. In 1980 a major role was established for the Procurement and Assistance Management Directorate in the development of policy. Specifically, that office will guide the award and administration of grants and cooperative agreements, guide the training of responsible personnel, provide advice and assistance to program offices, and review the performance of DOE offices that award and administer grants and cooperative agreements. The regulations governing the Department's award and administration of cooperative agreements were published in early 1980. DOE expects to amend its financial assistance regulations in 1981 in order to reflect changes in Government policies and procedures as well as to reflect the experience base resulting from DOE's use of grants and cooperative agreements.

Looking to the future, the Department has been identified as one of the major grant and cooperative agreement-making agencies in the Federal Government and will be participating in the development of guidance which will affect the Government and recipients for some years to come.