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Report to the Chairman, Subcommittee on Fossil and Synthetic Fuels, Committee on Energy and Commerce, House of Representatives

February 1987

ENERGY R&D

Changes in Federal Funding Criteria and Industry Response

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Resources, Community, and
Economic Development Division

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February 9, 1987

The Honorable Philip R. Sharp
Chairman, Subcommittee on Fossil and
Synthetic Fuels
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

In your letter of November 22, 1985, you asked that we examine the application of the Department of Energy's (DOE) research and development (R&D) policy of emphasizing long-term, high-risk, high-payoff technologies. This report responds to your request and analyzes (1) whether the DOE policy has been applied consistently across energy technologies and (2) whether energy R&D curtailed by DOE as a result of this policy has been picked up by private industry.

We concluded that DOE has generally applied the long-term, high-risk, high-payoff criteria consistently across energy R&D programs, although the civilian nuclear reactor budget has been an exception. We also found that the private sector has generally not compensated for cutbacks in DOE-sponsored R&D.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 7 days from its date of issue. At that time we will send copies to the Secretary of Energy; the Director, Office of Management and Budget; interested committees; subcommittees; individual Members of Congress; and other interested parties. Copies will be made available to others on request.

This work was performed under the direction of James Duffus III, Associate Director. Other major contributors are listed in appendix III.

Sincerely yours,

J. Dexter Peach
Assistant Comptroller General

Executive Summary

Purpose

The federal government has substantially reduced its support for energy research and development (R&D) since fiscal year 1981. Rather than supporting R&D along the entire continuum of the R&D process from basic research through commercialization, as was done during the 1970's, energy R&D policy has been reoriented to emphasize "long-term, high-risk, high-payoff" technologies in their early stages of development.

The Chairman, Subcommittee on Fossil and Synthetic Fuels, House Committee on Energy and Commerce, asked GAO to analyze (1) whether the Department of Energy (DOE), the agency primarily responsible for implementing the administration's energy R&D policy, is applying the long-term, high-risk, high-payoff criteria consistently across fossil, nuclear, and other energy technologies and (2) whether industry has undertaken the energy R&D curtailed as a result of the application of these criteria.

Background

The federal government has supported R&D for new energy technologies in conservation, nuclear energy, fossil energy, and other areas through national laboratories and contracts with private organizations. Energy price increases during the 1970's led it to increase its commitment to this research, particularly to expand its efforts to demonstrate and commercialize new technologies. Energy's share of the total federal R&D budget tripled between 1971 and 1979.

However, under the present administration, government support for many of these activities has decreased substantially. The reorientation of energy R&D policy and subsequent budget reductions reflect the administration's view that energy R&D in the latter stages of the R&D process, nearer to commercialization, is more appropriately the responsibility of the private sector.

Opponents of this policy, however, have asserted that DOE applies the long-term, high-risk, high-payoff criteria selectively, invoking them for technologies it desires not to fund but not adhering to them for technologies it supports. Opponents have also charged that curtailed energy R&D has generally not been picked up by industry, resulting in delays in developing emerging technologies.

Results in Brief

DOE has generally applied the long-term, high-risk, high-payoff criteria consistently across energy R&D technologies, reorienting most R&D activities toward the early stages of the innovation process. The civilian nuclear reactor R&D budget has been an exception, with DOE support for these technologies insulating them from major reductions in the early 1980's. Civilian reactor programs sustained substantial reductions beginning in fiscal 1984, but these reductions were based on other considerations as well as the long-term, high-risk, high-payoff criteria. These considerations included a perceived need to (1) address safety issues associated with reactors currently operating and (2) emphasize reactor technologies that satisfy certain military objectives.

There is little indication that the private sector has compensated for cutbacks in DOE R&D. Among the reasons are (1) market factors (such as low prices for oil and other conventional fuels) have generally reduced the potential profitability of technology development and (2) many of the activities curtailed by DOE have involved expensive demonstrations and other large-scale activities viewed as too risky to finance without government support. This has contributed to delays in technology development and, in some cases such as breeder reactors and photovoltaic energy, to an erosion of American technological leadership.

GAO's Analysis

Criteria Applied Consistently in Most Cases

The clearest evidence of DOE's reliance upon the long-term, high-risk, high-payoff criteria has been its strong funding of the General Science and Basic Energy Sciences programs, which are inherently consistent with these criteria. The fiscal year 1987 funding request for these programs represented a 63-percent increase over fiscal 1981 appropriations, while fiscal 1987 funding requests for fossil energy, renewable energy, conservation, and nuclear reactor R&D decreased by a total of 76 percent below fiscal 1981 levels.

In addition, DOE has sought to realign the Fossil, Conservation, and Renewable Energy budgets in keeping with these criteria. While there have been exceptions, GAO found that (1) demonstration projects, market development programs, and other activities closer to product commercialization have been substantially curtailed and (2) energy R&D programs have been reoriented to focus on activities associated with the earlier stages of the R&D process.

The criteria have generally not figured as prominently in funding decisions for nuclear reactor technologies. DOE's strong support for these technologies, reflecting an explicit policy to encourage development of the nuclear power option, insulated nearer- and longer-term programs alike from major budget cuts during the early 1980's. While the budget for civilian nuclear reactor R&D was reduced substantially in subsequent years, funding priorities reflected other considerations as well as these criteria.

Industry Pick-Up of Curtailed DOE R&D

GAO found little indication that the private sector has compensated for DOE's reduced support for energy R&D. Among the reasons are (1) market factors, such as falling oil prices and low growth in the demand for electricity, which have affected the profitability of technology development; (2) the high risk of investing in expensive demonstrations and other large-scale activities; and (3) lack of a strong industry infrastructure in some technology areas to pursue energy R&D without continued government support. The following summarizes GAO's findings by technology area:

Fossil energy. The elimination of large coal conversion demonstration projects accounts for most of the reductions in the fossil energy budget during the past 6 years. None of these projects has been picked up by the private sector, although knowledge gained from them may have contributed to ongoing R&D in this area. In other areas, such as utility-related applications of coal and natural gas research, congressional restoration of funds deleted by DOE has kept many affected industry research programs alive, although at reduced levels.

Nuclear energy. Most curtailed nuclear reactor R&D has been long-term research related to future generations of reactors, such as breeder reactors. This R&D has generally not been picked up by the private sector because the nuclear industry, reacting to a lack of demand for new reactor orders, has focused its own resources on ways to improve existing nuclear power plants. The fiscal 1987 DOE nuclear energy budget proposed that much of the remaining long-term reactor work be reoriented to meet military objectives. Few of these militarized R&D programs, however, have significant application to civilian reactor needs, according to energy R&D experts and reactor vendors GAO contacted.

Renewable energy. Renewable technologies vary considerably in the extent to which industry has pursued R&D following reduced DOE support. Key factors are the market outlook for each technology and related questions, such as prices of competing conventional fuels, tax policies, and the existence of a stable industry with the resources to perform R&D. Photovoltaic energy is one technology with substantial industry resources behind it and strong commercial prospects. The U.S. photovoltaic industry has undertaken considerable R&D in the wake of DOE budget cuts, although its relative position in the world market has fallen because of foreign competition. On the other hand, solar thermal central receivers and active solar heating and cooling are technologies that have depended more heavily on DOE for their development and that have been affected substantially by declining DOE R&D support.

Conservation. Many industries pursued conservation R&D aggressively in the 1970's and developed important energy efficiency improvements that are in use today. In the 1980's, however, industries' conservation R&D efforts have varied widely as energy prices have fallen and DOE has reduced its R&D support. Some, notably the transportation sector, have had stronger capabilities and incentives to perform this R&D. Others, particularly the building sector, have had few incentives for industry involvement largely because their fragmented infrastructure is not conducive to such investments. Substantial conservation R&D in these areas is unlikely to be pursued without continued DOE support, particularly if conventional energy prices remain low.

Implications for U.S. Energy Security

Reduced DOE and industry support for energy R&D has delayed U.S. technology development. The future price and availability of conventional energy sources will determine the effect of this delayed development on U.S. energy security. Should energy prices rise relatively quickly and substantially in the future, as they did in past oil disruptions, then delays in developing alternative energy technologies could be very costly. On the other hand, such delays may have little effect on U.S. energy security if conventional energy sources remain available at reasonable cost well into the future.

Recommendations

GAO is making no recommendations.

Agency Comments

DOE agreed with the report's findings and conclusions but cited some matters that it said should be clarified. DOE's comments and GAO's responses are included in appendix II.

Contents

Abbreviations

BCS	Buildings and Community Systems
CCTR	Clean Coal Technology Reserve
CRBR	Clinch River Breeder Reactor
CRS	Congressional Research Service
DOE	Department of Energy
EIA	Energy Information Administration
ECUT	Energy Conversion and Utilization Technologies
EMD	Energy and Minerals Division
EPRI	Electric Power Research Institute
ERAB	Energy Research Advisory Board
GAO	General Accounting Office
GRI	Gas Research Institute
HTGR	High-Temperature Gas-cooled Reactor
LWR	light water reactor
MW	megawatt
OTA	Office of Technology Assessment
PURPA	Public Utility Regulatory Policies Act
PV	photovoltaics
R&D	research and development
RCED	Resources, Community, and Economic Development
SDI	Strategic Defense Initiative
SEIA	Solar Energy Industries Association
SFC	Synthetic Fuels Corporation
SRC	solvent refined coal

Chapter 1

Introduction

Background

Federal support for energy research and development (R&D) has moved through several phases since the early 1970's, reflecting changes in both international energy markets and government policy. During the early 1970's, the federal government focused its support on the nation's developing civilian nuclear reactor industry. However, this limited federal energy R&D role increased greatly after the Arab oil embargo and subsequent energy crises during the 1970's. The government retained its nuclear R&D role and developed and expanded programs in renewable energy, fossil energy, and conservation through the end of the decade.

The Debate Over Energy R&D Policy in the 1980's

A policy debate during the 1980's has centered on the extent to which the federal government should continue to support energy R&D, and where along the technology development path the government should relinquish responsibility for technology development to the private sector. The Department of Energy's (DOE) fiscal year 1987 budget proposal describes the technology path as consisting of five stages:

- Basic research seeks to develop fundamental scientific knowledge, including a fundamental understanding of the physical and chemical properties.
- Applied research includes activities to resolve broad engineering and physical science problems in specific technologies and related areas.
- The proof-of-concept stage is the point at which enough has been learned to resolve specific problems to determine the feasibility of an innovation.
- Process development is directed at increasingly larger scale engineering design, construction, and operation of energy systems (such as demonstration plants) with the objective of reducing technical risks and improving the innovation's operability, reliability, economics, and environmental impact.
- Commercialization, the final stage, involves efforts to remove technical, economic, and institutional barriers required for acceptance of a new energy technology in the marketplace.

In the wake of the energy supply disruptions of the 1970's, past administrations determined that energy R&D should be supported along this entire continuum to help reduce the nation's dependence on foreign oil. The present administration, however, facing a relatively stable energy market, scaled back energy R&D to (1) deal with the federal deficit, (2) reduce the size and scope of government, and (3) reflect its philosophy that the private sector is better suited to perform R&D in the latter stages of the technology development path. DOE, as the agency primarily responsible for implementing the administration's energy R&D policy, has stated that it would emphasize support for "long-term, high-risk, high-payoff" technologies in the early stages of their development—from basic research to proof-of-concept—when the risk is greatest and the time to payoff is far in the future. The latter stages of this process, where risks are more easily defined and predictable, were deemed to be the responsibility of the private sector.

The Controversy Over the Long-Term, High-Risk, High-Payoff Policy

Two issues that have arisen in connection with this policy are (1) whether the long-term, high-risk, high-payoff criteria have been applied consistently across energy technologies and (2) whether reduced DOE funding, caused by the application of these criteria, has led to delays in developing promising energy technologies because curtailed R&D efforts have not been picked up by the private sector.

The first issue deals with concerns over whether DOE has applied the criteria selectively, invoked the long-range, high-risk policy for those technologies which it desires not to fund but not adhering to that policy for projects that it supports. It has been suggested, for example, that the criteria have been applied less stringently to nuclear than to nonnuclear programs.

With respect to the second issue, those favoring a greater federal role in energy R&D have expressed concern that the present policy has the government pulling out at precisely the time the innovation becomes too costly for industry to pursue on its own—during the process development and commercialization stages. A funding gap is thus created during this process of "scaling-up."

Opponents of the administration's energy R&D policy have asserted that the focus on long-term, high-risk, high-payoff, and the sharp cuts in federal support for energy R&D that it has spawned, is short-sighted and may exact a heavy price from the nation if energy prices rise sharply again, as they did in the 1970's. They also say that, under this policy, the United States can expect a continued erosion of its lead in solar photovoltaics, advanced nuclear reactors, and other energy technologies; countries whose governments actively support energy technology development are rapidly gaining ground.

Objectives, Scope, and Methodology

The Chairman, Subcommittee on Fossil and Synthetic Fuels, House Committee on Energy and Commerce, requested that we examine the application of DOE's policy of emphasizing long-term, high-risk, high-payoff technologies. Specifically, we were asked to (1) "investigate and analyze the application of R&D policy and whether it is being applied fairly across the board" and (2) examine the "extent to which R&D efforts curtailed by the administration as a result of the new policy have been picked up by private industry." (See app. I.)

In responding to these questions, we focused on DOE programs in the fossil, nuclear reactor, renewable, and conservation energy budgets. We also examined the General Science and Basic Energy Sciences budgets. Together, these programs cover the large majority of energy supply and demand R&D options being pursued within industry and government.[1]

In addressing the first issue, we focused on the consistency with which the long-term, high-risk, high-payoff criteria played a role in funding decisions. However, we did not evaluate the merits of these criteria, nor did we assess the proper role of the federal government in energy R&D. Therefore, identification of technologies as more closely fitting the long-term, high-risk, high-payoff criteria should not be considered an endorsement of these technologies.

In addressing the second issue, we limited our review to whether private industry has picked up R&D efforts curtailed by DOE and, to the extent possible, the effect these curtailments have had on the development of energy technologies they were intended to advance. We did not examine whether such R&D efforts may have had other benefits through alternative applications that were tangential to their original purpose.

The following discusses the approach and methods used to address each of the issues covered in our analysis.

Consistency in Applying the Long-Term, High-Risk, High-Payoff Criteria

In addressing this issue, we first determined the extent to which DOE officials had defined the long-term, high-risk, high-payoff criteria. It might be expected that specific definitions for these criteria would be needed if they were to be applied systematically in making R&D funding decisions. As we note in chapter 2, however, all DOE program officials interviewed explained that the criteria are treated as a general policy

[1] Major R&D programs in the DOE budget that are outside the scope of this study relate to weapons programs, naval reactor development, and uranium enrichment.

goal but have not been defined, nor have they been applied, in a rigid or systematic fashion.

In the absence of precise definitions for the criteria, we relied on technical opinion and consensus to identify which technologies and programs may be considered "long-term, high-risk, high-payoff." Among the major scientific analyses we used were reports by DOE's Energy Research Advisory Board (ERAB), an independent group that advises DOE on matters related to energy R&D, which evaluated various energy technologies according to standards that strongly emphasized long-term, high-risk, high-payoff criteria.

We then examined the budget histories of these technologies between fiscal years 1981 and 1987, using DOE's budget requests to the Congress as indicators of the agency's R&D policy. The approved fiscal year 1981 budget was chosen as a starting point to identify, to the extent possible, the evolution of DOE's energy R&D budget under the present administration's policies. (Fiscal year 1981 was the last budget to reflect priorities and policies of the prior administration.) We also examined other documents, such as strategic and long-range plans, that explained R&D objectives and how funding strategies were designed to meet them. We compared funding proposals with the recommendations of ERAB and, where possible, other scientific experts, using the long-term, high-risk, high-payoff criteria. As a check on our findings, we interviewed ERAB members and other experts concerning the extent to which DOE's programs have been oriented toward long-term, high-risk, high-payoff programs.

In applying this test to various energy technologies, we first examined whether categories consisting exclusively of long-term, high-risk, high-payoff programs have been funded comparatively well. We would expect these programs (such as the General Science and Basic Energy Sciences budget categories) to be funded well if DOE were applying its criteria consistently because activities performed in these areas are in the early stages of the technology development path.

We then examined programs in the Fossil Energy, Nuclear Energy, Renewable Energy, and Conservation areas to determine whether funding priorities within these areas have been consistent with the criteria. Key measurements were (1) whether technologies generally agreed by ERAB and other scientists to be of a long-term, high-risk, high-payoff nature have been supported comparatively well and (2) the extent to which activities clearly falling outside these criteria, such as demonstration projects and marketing activities, have been curtailed or continued.

Industry Support for Discontinued DOE R&D

We first examined pertinent studies to determine whether they adequately explain the impact of federal funding cuts on energy spending in the private sector. We found that most of them discussed private sector activities but did not connect these activities with DOE funding policies or budget reductions.

We then gathered available data on how much money the private sector is spending on energy R&D, attempting to identify (1) the major energy R&D performers, (2) how funds are used to support specific technologies, and (3) trends in private sector funding during the time that DOE budget cuts were being implemented.[2] However, except for some aggregate data on major energy companies, the utility industry, and major private research organizations (obtained from DOE's Energy Information Administration), such data are often fragmented and, in many instances, proprietary. Therefore, we had to perform a more detailed assessment of private sector energy R&D, focusing on how these activities have been affected by cutbacks in DOE R&D support.

Private Sector Energy R&D Activities

We focused our analysis of private sector energy R&D on the key industry organizations that perform a substantial portion of the private sector's energy R&D. Such organizations, particularly the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI), perform R&D across a wide range of energy technologies. In determining the effect of DOE R&D budget reductions on their R&D agendas, we examined R&D planning and strategy reports and other documents and interviewed executive officials and program managers to more precisely identify the impacts of DOE funding policies on programs and specific projects (particularly activities co-funded with DOE).

We also interviewed officials from, and reviewed documents supplied by, major industry trade organizations to obtain as much information as possible about diverse industries from central sources. Although some of

[2] Whereas our response to the first question focuses primarily on proposed spending levels from fiscal years 1982 to 1987 as an indication of administration use of the long-term, high-risk, high-payoff criteria, our response to this question deals more with actual energy R&D spending by DOE and private industry. Accordingly, to address this question, we have drawn comparisons between actual DOE R&D appropriations in fiscal year 1981 (the last year in which actual appropriations reflected the prior administration's priorities) and fiscal year 1986 (the most recent year for which actual appropriations are available).

these organizations supplied us with comprehensive information on energy R&D performed by their constituents, many have limited data about energy R&D in their industries, particularly in relationship to the DOE program. To supplement these data, we contacted individual companies with major energy R&D programs, such as oil companies, utilities, and utility equipment manufacturers. We focused on (1) the type of energy R&D these companies are pursuing, (2) the extent to which they depend on DOE R&D support, and (3) how DOE's funding decisions have affected their R&D efforts.

We performed our work in accordance with generally accepted government auditing standards.

Has DOE Applied the Long-Term, High-Risk, High-Payoff Criteria Consistently Across Energy Technologies?

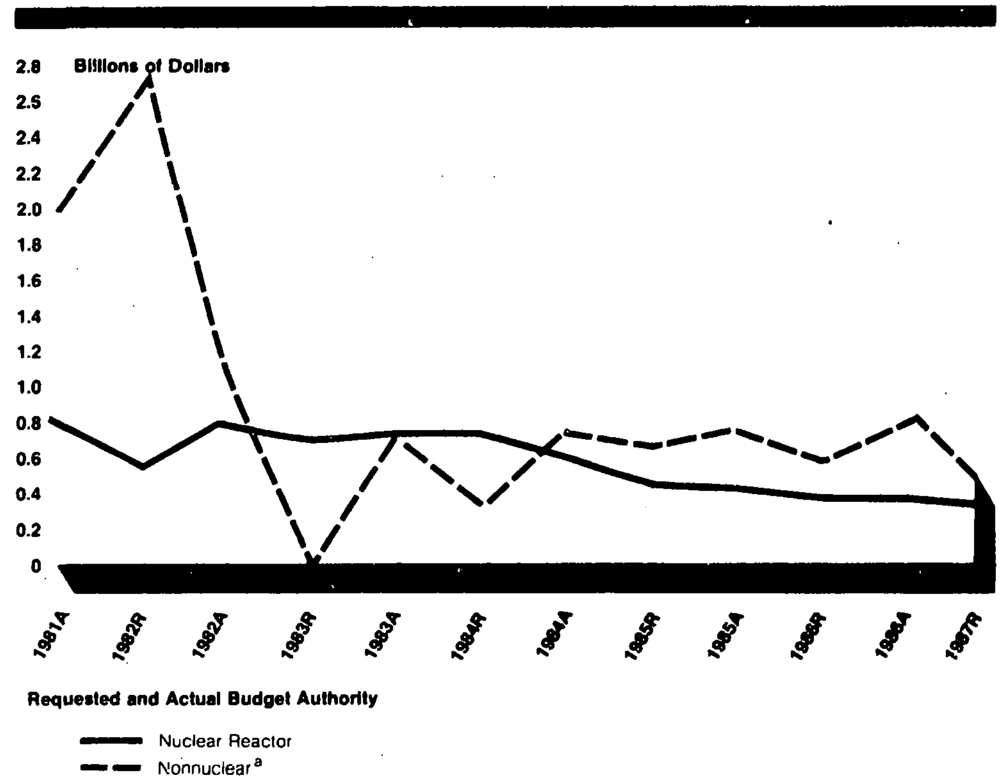
In general, DOE has consistently applied the long-term, high-risk, high-payoff criteria across energy R&D programs since fiscal year 1981, reorienting most R&D activities toward the earlier stages of the innovation process. The civilian nuclear reactor R&D budget presents a somewhat different picture, however; DOE support for these technologies has insulated them from major reductions in the early 1980's. Civilian reactor programs sustained substantial reductions beginning in fiscal year 1984, but these reductions were based on a decision to emphasize military uses of reactor R&D and other considerations as well as the long-term, high-risk, high-payoff criteria.

This chapter first examines trends in DOE's proposed and approved R&D budgets since fiscal year 1981 to provide general perspective and to show (1) which technology areas DOE has chosen to emphasize and deemphasize, (2) the impact of congressional policy in restoring or further reducing funding in different technologies, and (3) the effect of the DOE policy on energy R&D spending during the past 6 years. It then examines how consistently these trends can be explained by DOE's application of its long-term, high-risk, high-payoff criteria.

Trends in DOE's R&D Funding

Figure 2.1 shows DOE funding for energy technologies from fiscal year 1981 through the fiscal year 1987 proposal, showing aggregate funding levels for nuclear reactor and nonnuclear technologies. Proposed budget authority for each year is provided as an indicator of DOE's budgetary priorities, followed by actual budget authority for each year which reflects congressional prerogatives and priorities.

Figure 2.1: DOE R&D Budget Authority



[a]Includes Fossil Energy (plus Clean Coal Technology Reserve), Renewable Energy, and Conservation R+D budgets.

An examination of figure 2.1 reveals several important trends reflecting both DOE priorities and the Congress' reaction. First, it shows that DOE continued to propose sharp cuts in fossil energy, conservation, and other nonnuclear technologies after the prior administration's fiscal year 1982 DOE budget proposal, but that the Congress restored many of these cuts. This "sawtooth" pattern in nonnuclear funding was particularly pronounced during fiscal years 1983 and 1984.

Second, DOE support for nuclear reactor programs remained relatively constant during this period, compared to nonnuclear programs. However, DOE proposed, and the Congress agreed to, significant cuts in nuclear reactor programs for fiscal year 1985.

Third, the sharpest cuts in congressional appropriations for nonnuclear technologies came in fiscal years 1982 and 1983. Funding for these technologies remained relatively stable in subsequent years, due largely to congressional restoration of DOE proposed cuts.

These aggregate budget data reveal some useful information about funding trends and priorities during the past 6 years. However, they do little to clarify whether DOE has applied the long-term, high-risk, high-payoff criteria consistently across technologies. For example, broad categories reflected in the budget numbers—fossil energy, solar, conservation—conceal a variety of programs and individual projects that may span the spectrum from basic research through commercialization.

Therefore, it requires substantially more analysis and explanation of the DOE R&D budget to determine whether the criteria have been applied consistently in making energy R&D funding decisions. This requires (1) identifying technologies that are long-term, high-risk, high-payoff in nature and (2) comparing the relative support for technologies fitting these criteria with technologies falling outside them.

Identifying Technologies That Are "Long-Term, High-Risk, High-Payoff"

To measure precisely which technologies meet the long-term, high-risk, high-payoff criteria would require fairly specific definitions. If, for example, "long-term" were defined as requiring a certain number of years to achieve proof-of-concept or commercialization, then technologies could be more easily evaluated as either meeting or not meeting that criterion.

However, as noted in chapter 1, our interviews with officials in DOE's Offices of Fossil Energy, Nuclear Energy, Renewable Energy, and Conservation confirm our earlier findings that specific definitions are not used in making funding decisions.[1] Rather, we were told that these criteria were used as general guidelines in evaluating alternative technologies and that other criteria were often considered as well in making funding decisions.

In the absence of specific definitions for "long-term, high-risk, high-payoff," we relied on DOE's ERAB and other experts to provide guidance on which technologies most clearly meet these criteria and which do not.[2] In some cases, these judgments are easily supported and noncontroversial. For example, experts generally agree that DOE's Magnetic Fusion and Basic Energy Sciences programs are clearly long-term, high-risk,

[1] Analysis of the Energy Research and Development Budget Proposal Process (GAO/RCED-83-6, Nov. 5, 1982), p. 6.

[2] The methodology we used to identify how well various programs fit the long-term, high-risk, high-payoff criteria is described in more detail in chapter 1.

and potentially high-payoff programs that offer few incentives for sufficient private sector support. Similarly, programs involving technologies that have reached the demonstration or commercialization stages clearly do not meet all of these criteria.

For technologies between these extremes, judgments about technologies' consistency with the long-term, high-risk, high-payoff criteria become more subjective and should be interpreted with caution. Nevertheless, even for these, relative statements about which technologies more closely fit the criteria may still be made.

Has DOE Emphasized Technologies That Best Fit These Criteria?

We first examine in this section whether budget categories that emphasize basic research have been funded favorably compared to categories that contain other types of R&D activities, such as applied research and process development. We then examine the range of nuclear reactor and nonnuclear technologies to determine whether funding priorities within various program areas have been consistent with these criteria.

Basic Research Programs Have Been Emphasized

"General Science" and "Basic Energy Sciences" are categories that best meet the DOE budget criteria. The fiscal year 1987 DOE budget states that the General Science programs support basic research to "discover and understand the fundamental constituents of matter and energy and the basic forces in nature." Basic Energy Sciences programs are "responsible for generic, long-range energy-related research in support of both nuclear and nonnuclear energy technologies." This category includes energy-related research and the operation of research facilities in the physical and biological sciences, engineering, applied mathematics, and geosciences. In addition, ERAB has consistently supported a federal role in these areas, noting in its 1983 Federal Role Panel report that they are "inherently long-term in character and high-risk in terms of being able to identify the practical consequences of any individual project . . . ."[3] It also stated that "It has therefore been long established that the Federal Government must play a primary role in the support of the[se] important research programs . . . ."

[3]The Federal Role in Energy Research and Development, Energy Research Advisory Board (DOE/S-0016, Feb., 1983), p. 23.

Figure 2.2: Basic Energy and General Sciences Budget Requests, FY 1982-1987

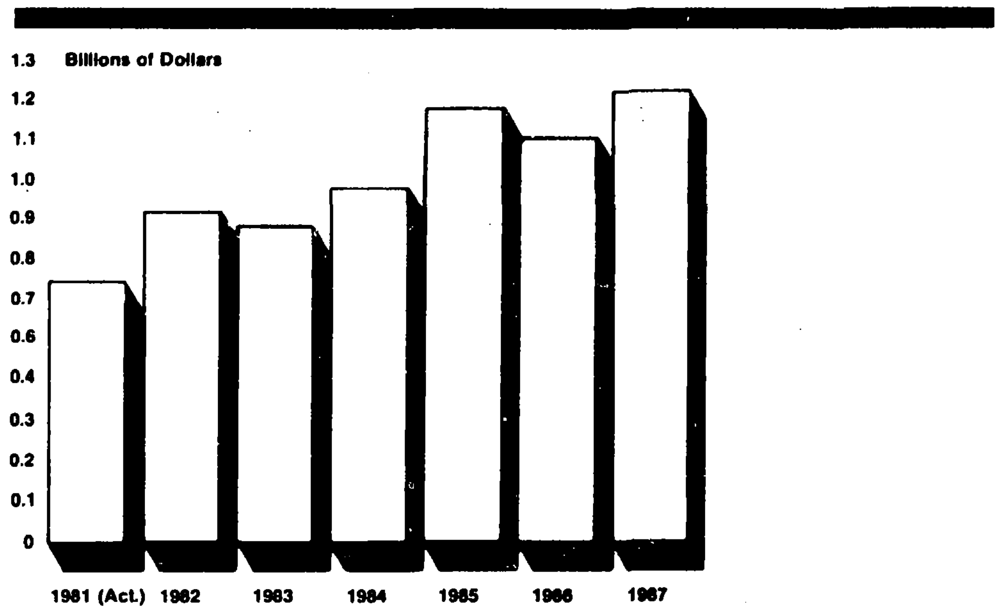
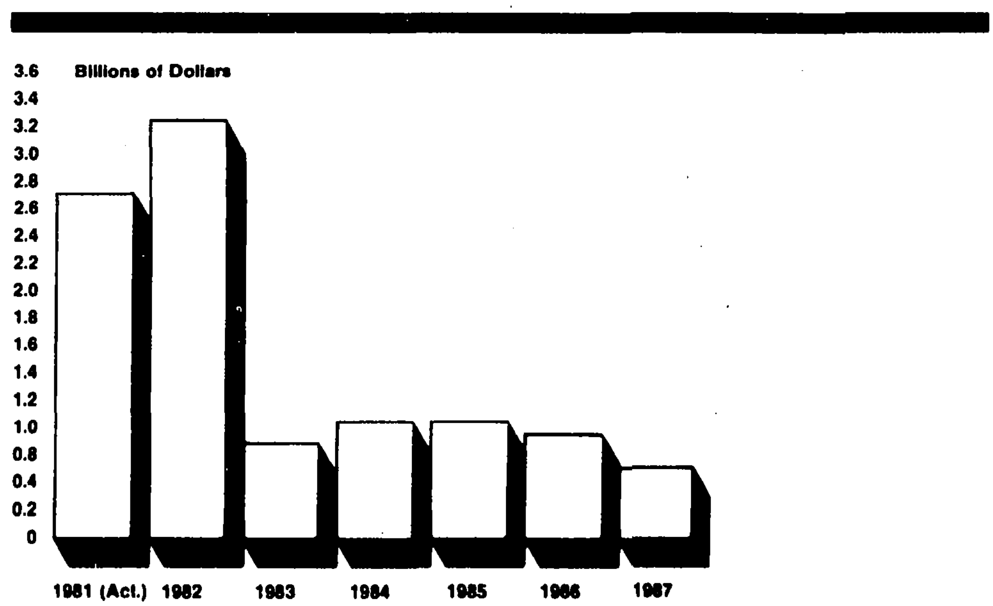


Figure 2.3: Other Energy Technologies' Budget Requests, FY 1982-1987



[a]Includes Fossil Energy, Renewable Energy, Nuclear Reactor, and Conservation budgets.

Figures 2.2 and 2.3 show clearly that these categories have been well supported in DOE budget requests, compared to other budget categories consisting of a mix of long- and short-term R&D. Budget authority for Basic Energy Sciences and General Science programs rose from $744 million in the approved fiscal year 1981 budget to $1.21 billion in the fiscal year 1987 proposal—an increase of about 63 percent. Budget authority for the other energy technologies, fossil, renewable, conservation, and nuclear reactor R&D, dropped about 76 percent during the same period from $2.75 billion to $660 million.

Thus, comparatively strong funding requests for Basic Energy Sciences and General Science, which are inherently long-term and high-risk in nature, supports the contention that DOE's criteria have indeed weighed heavily in the agency's R&D funding decisions. Below, we examine the extent to which these criteria have been applied in funding other technology areas.

Funding in Nonnuclear Energy Technologies Has Generally Emphasized DOE's Criteria

In general, DOE budget proposals during the past 6 years have emphasized programs and projects in the fossil energy, renewable energy, and conservation areas that are long-term, high-risk, and high-payoff in nature. We found (1) a clear deemphasis of demonstration projects and other activities that are generally closer to commercialization along the R&D continuum and (2) comparatively strong funding of technologies during this period that more closely fit the long-term, high-risk, high-payoff criteria.

Most Demonstration Programs Have Been Terminated

Technology demonstrations generally follow the proof-of-concept stage in the R&D process and represent a phase of technological maturity which, according to DOE policy, is more appropriate for private sector rather than public sector support. We found that DOE has been fairly consistent since fiscal year 1981 in reorienting its fossil, conservation, and renewable energy programs away from demonstration activities.

Fossil energy demonstrations—Demonstration projects have been virtually eliminated from the fossil energy budget during the past 6 years, along with pilot plants and other elements of the program considered closer to commercialization. These projects, discussed in greater detail in chapter 3, related primarily to synthetic fuel technologies, particularly coal liquefaction and coal gasification. DOE funding in these areas declined from almost $600 million in fiscal year 1981 (more than half of which supported development of two liquefaction demonstration plants) to $77 million in fiscal year 1986. According to information supplied to us by DOE, the agency's demonstration programs were formally terminated in January 1981, and since that time, all activities associated with the demonstation plants have related to contract closeout.

The Clean Coal Technology Reserve (CCTR) has been the major exception to this trend in fossil energy programs. In its fiscal year 1987 budget, DOE says that this program was established to "provide financial assistance for the construction and operation of clean coal technology projects to demonstrate their feasibility for future commercial applications." The program was funded at $99.4 million in fiscal year 1986 and $149.1 million in fiscal 1987.

While clearly a demonstration program, however, funding for the CCTR was initiated primarily by the Congress, not DOE. In fact, DOE had initially opposed the CCTR because it ran contrary to its philosophy of limiting federal R&D support to the earliest stages of the R&D process.

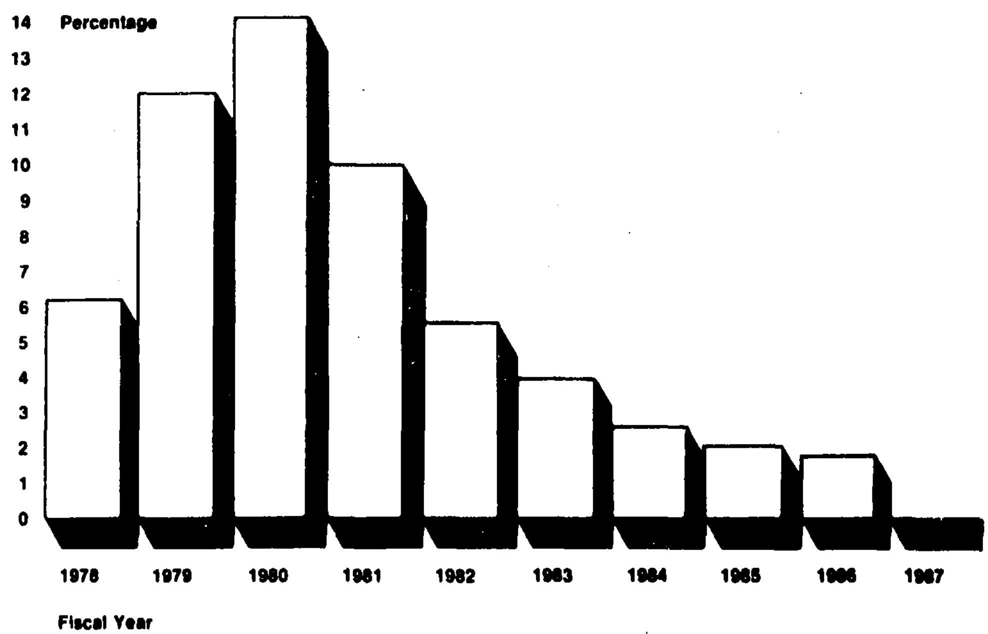
Renewable energy demonstrations—DOE also applied a general policy of eliminating demonstration projects in solar and renewable technologies. In an April 1983 report,[4] we noted that DOE's past solar program efforts had involved the construction and operation of various solar energy projects to give the associated technologies public visibility and to obtain information on the respective solar energy systems' performance. However, "DOE's current policy . . . is to close out these projects in order to redirect program activities toward long-term, high-risk research efforts . . . ."

A March 1982 memorandum from the Assistant Secretary for Conservation and Renewable Energy elaborated on this policy, stating that "It is CE [Conservation and Renewable Energy] policy that we should disengage from completed market test demonstration/experiment type projects as quickly as possible." DOE officials told us at that time that the intention of closing such projects was to take DOE "out of the demonstration business" and put it more in line with the administration's philosophy of concentrating on long-term, high-risk R&D with high potential payoff, leaving near-term R&D and commercialization to industry to perform.

[4] Prospects for Continued Operation of DOE's Solar Test Facilities and Selected Aspects of Its Solar Project Closeouts (GAO/RCED-83-120, Apr. 21, 1983), p.7.

Conservation demonstrations—The conservation R&D budget has also been characterized by a decreased emphasis on demonstration programs. Figure 2.4 shows that demonstration activities peaked in the early 1980's. These activities included a wide range of projects such as demonstrations of residential and commercial appliances, demonstrations of innovations in industrial fuel uses and combustion efficiency improvements, demonstration and testing of vehicle propulsion systems, and market demonstrations for electric and hybrid vehicles. DOE's demonstration work in the conservation area then declined steadily through fiscal year 1986, and none was proposed by DOE in fiscal year 1987.

Figure 2.4: Demonstration Projects' Share of Energy Conservation R&D Budget



Source Department of Energy. FY 1988 Energy Conservation Multi-Year Plan.

DOE Funding Has Emphasized Technologies That More Closely Fit Its Criteria

Beyond DOE's disinclination to fund demonstration programs and pilot plant projects in major nonnuclear programs, our examination of the Fossil Energy, Conservation, and Renewable Energy programs reveals that other program activities have generally been reoriented toward technologies more closely fitting the long-term, high-risk, high-payoff criteria.

Fossil Energy programs—The Fossil Energy program's emphasis on long-term, high-risk, high-payoff R&D is illustrated by the change in priorities in the coal budget. The coal budget, which accounted for more than half of the proposed fiscal year 1987 Fossil Energy budget, includes fuel cells, liquefaction, advanced technology, and several other categories. "Advanced technology" is the category most clearly fitting the long-term, high-risk, high-payoff criteria. ERAB's Federal Role Panel describes it as R&D that should be "as close to the frontiers of knowledge as possible," generic in nature, and exploring areas "of high-risk, long-term, high-potential impact."[5]

We would expect advanced technology to receive budgetary preference if long-term, high-risk, high-payoff technologies were being emphasized, and, in fact, this has been the case. While advanced technology accounted for only 7 percent of the fiscal year 1981 coal budget, its share rose to 33 percent in the fiscal year 1987 proposal and represented the largest single item in the coal budget.

We also found a general emphasis on long-term, high-risk, technologies in the petroleum and gas portions of the Fossil Energy budget. A December 1985 ERAB report observed that since 1981, DOE has reduced its funding of near-term petroleum research and demonstration activities "to focus on longer-term, higher-risk research."[6] DOE's primary focus in its proposed $4.5 million fiscal year 1987 Enhanced Oil Recovery budget, for example, is basic research that is aimed at understanding why residual oil is trapped or by-passed in a reservoir. Its shale oil program has shifted from demonstration projects sponsored in the late 1970's and early 1980's toward fundamental research and experiments.

DOE's reorientation of its gas research budget toward long-term, high-risk technologies is articulated in agreements with the Gas Research Institute (GRI) to coordinate R&D programs of mutual interest. DOE and GRI agreed to emphasize long-term and near-term programs, respectively. GRI referred us to agreements on "Western tight gas sands" and fuel cells research as examples of how GRI and DOE have successfully divided near- and long-term R&D responsibilities. GRI stated, however, that DOE proposed in fiscal year 1987 to discontinue much of its own long-term R&D as well.

[5]The Federal Role in Energy Research and Development, p. 12.

[6]Guidelines for DOE Long Term Civilian Research and Development, Vol. VI, Supply, Energy Research Advisory Board (DOE/S-0044, Dec., 1985), p. 43.

Conservation programs—DOE's emphasis on long-term, high-risk, high-payoff R&D in the conservation budget is most clearly illustrated by its comparatively strong support for Energy Conversion and Utilization Technologies (ECUT). ECUT involves basic and applied research in support of the other Conservation R&D programs, including work on new insulation materials, improved heat exchanger materials, improved internal combustion engines, and many other areas. ERAB's 1983 Federal Role Panel report described ECUT R&D as "generally of a longer-term nature, applicable to many end-use sectors and ultimately promising high payoffs."

While Conservation R&D programs declined by 76 percent between fiscal year 1981 funding and the fiscal year 1987 budget proposal, support for ECUT rose 92 percent during the same period. Moreover, ECUT's share of the conservation budget increased from 3 percent to 21 percent.

DOE's support for the other three main components of the Conservation program—transportation, industrial, and buildings and community systems (BCS)—has been much weaker, as would be expected with a focus on long-term, high-risk, high-payoff R&D. Indeed, the fiscal year 1983 budget proposed to eliminate the transportation, industrial, and BCS programs, transferring only their basic research components to the ECUT program.

The Congress restored most of the funding for these programs in fiscal year 1983, however, as it did to the less drastic cuts proposed in subsequent years. DOE's proposals have since continued to emphasize R&D at the beginning of the R&D continuum, but have not focused as much on a rigid adherence to "long-term, high-risk, high-payoff" criteria. Its fiscal year 1987 Energy Conservation Multi-Year Plan asserts, for example, that

"... the federal [R&D] role is appropriate when two conditions are met. The first is that the focus of the work has overriding national significance .... The second is that there exists a non-technical reason why the private sector has failed to act."[7]

The plan nevertheless states that this guidance usually results in federal R&D at the beginning of the R&D spectrum, and that the Conservation program has become increasingly weighted toward the early phases of R&D since 1981.

[7]FY 1987 Energy Conservation Multi-Year Plan, U.S. Department of Energy, Office of Conservation, July, 1985, p. 34.

Renewable Energy programs—According to DOE's Deputy Assistant Secretary for Renewable Energy, DOE policy in this area has been to follow the long-term, high-risk, high-payoff criteria as a general goal, but not to apply it in all circumstances and according to specific definitions. The photovoltaics budget during the past few years illustrates how this policy has been carried out. The budget exhibits a general adherence to the criteria while also considering other criteria. A July 1985 Office of Technology Assessment (OTA) analysis of photovoltaics and other electric power technologies observed that federal support for photovoltaics during the first half of the 1980's shifted considerably in emphasis toward high-risk R&D with potentially high payoffs.[8] It noted, however, that limited demonstration work was still being supported and that export promotion assumed a more prominent position in the DOE program.

Other Renewable Energy programs also exhibit a clear emphasis on longer-term, higher-risk R&D, but with occasional deviations from this trend:

- Wind: A 1983 Congressional Research Service (CRS) analysis concluded that activities in the wind energy program shifted away from commercialization and engineering efforts under the prior administration toward long-term, high-risk R&D under the present administration.[9] An official in DOE's Renewable Energy Office told us that the agency's strategy in reducing the wind budget has been to cut back on costly, large demonstration projects while retaining R&D programs, and that the R&D technologies presently funded are intended to apply to the wind industry at large, rather than to individual companies. Wind budget data during the past few years support this contention, revealing increased emphasis on aerodynamics and structural dynamics research and a proposed phasing out of large-scale wind systems. Some smaller-scale demonstration work, however, is still proceeding in collaboration with industry.
- Solar thermal: DOE's Solar Thermal Technology program exhibited a similar trend away from large-scale demonstration projects toward long-term, high-risk R&D. Officials in DOE's Office of Renewable Energy explained to us that, particularly in light of present budget constraints and lower energy demand, paying the high cost of such facilities—up to

[8]New Electric Power Technologies: Problems and Prospects for the 1990s, Office of Technology Assessment (OTA-E-246, July, 1985), p. 255.

[9]Handbook of Alternative Energy Technology Development and Policy, Congressional Research Service (83-43 SPR, March 1, 1983).

$500 million in the case of a 30 megawatt solar thermal central receiver—could not be justified. The program's emphasis has therefore shifted away from constructing such facilities toward reducing the cost and risks of system components.

- Solar buildings: This program involves activities previously categorized under the (1) active solar heating and cooling and (2) passive and hybrid solar programs. The prior administration's fiscal year 1982 DOE budget proposal emphasized commercialization and market development efforts, including assistance in developing codes and standards, installer training and certification programs, and demonstrations of solar buildings systems. These activities were cut back substantially in subsequent years and reoriented toward more fundamental research in building materials and design methods.
- Geothermal energy: DOE's Geothermal program has also phased out its commercialization projects except for one at Heber, California. Consistent with the long-term, high-risk, high-payoff criteria, the program has been reoriented toward resolving technical problems and long-term generic research. Within the existing research program, however, DOE officials told us that funding decisions are made on a case-by-case basis and that "long-term, high-risk" criteria are not uniformly applied. For example, magma energy extraction research was cited as the longest-term, highest-risk technology in the Geothermal Energy Program, but it did not receive the highest priority.

In summary, the thrust of DOE's nonnuclear programs has evolved during the past several years toward long-term, high-risk, high-payoff programs in line with stated DOE policy. With some exceptions, we have found that (1) demonstration projects, marketing programs, and other activities closer toward product commercialization have been curtailed or eliminated and (2) R&D programs have generally been reoriented during this period to focus increasingly on activities more associated with the early stages of the R&D continuum.

The Criteria Have Not Figured as Prominently in Nuclear Reactor Funding Decisions

The importance of the long-term, high-risk, high-payoff criteria in nuclear reactor R&D spending decisions has varied considerably during the past 6 years, reflecting substantial shifts in program priorities and objectives. Generally, these criteria have not figured as prominently in funding nuclear reactor technologies as they have in nonnuclear technologies. We identified several distinct phases in the shaping of the nuclear reactor budget:

- Fiscal years 1982-84. Nuclear reactor programs received strong DOE support irrespective of the long-term, high-risk, high-payoff criteria. The centerpiece of the program was the Clinch River Breeder Reactor (CRBR) program.
- Fiscal years 1985-86. After the Congress terminated the CRBR program during the fiscal year 1984 budget process, DOE proposed sharp cutbacks in advanced reactor R&D and began to reorient its light water reactor programs. The long-term, high-risk, high-payoff criteria were important in establishing priorities in each of these areas.
- Fiscal year 1987 proposal. Civilian reactor programs were targeted for substantial reductions, but these reductions had more to do with a decision to emphasize military uses of reactor R&D rather than the long-term, high-risk, high-payoff criteria.

Nuclear Reactor R&D Initially Enjoyed Strong DOE Support (Fiscal Years 1982-84)

Nuclear reactor programs generally enjoyed strong support from DOE in the early 1980's while many nonnuclear programs were being substantially reduced because they were outside DOE's long-term, high-risk, high-payoff criteria. We acknowledged this preferential treatment of nuclear energy, and its relative insulation from the long-term, high-risk, high-payoff criteria, in our November 1982 analysis of DOE's budget process:

> "Nuclear energy received continued high funding because of a different criterium, the presidential Nuclear Policy Statement. That statement expressed support for continued Federal nuclear activities . . . . By contrast to this nuclear policy criterium, OMB officials proposed reduced funding for the technology areas of fossil and renewable and conservation because many of these activities, in their view, fall outside the 'long-term, high-risk, high-payoff' criteria and that industry will or should be responsible for their funding."[10]

Perhaps the clearest indication of the different application of the long-term, high-risk, high-payoff criteria to nuclear and nonnuclear programs was DOE's strong support for the CRBR—a project whose federal funding was terminated by the Congress in fiscal year 1984 against DOE's wishes. While the CRBR dealt with a long-term, high-risk technology that

[10] Analysis of the Energy Research and Development Budget Proposal Process (GAO/RCED-83-6, Nov. 6, 1982), p. 9. The President's October 8, 1981, Nuclear Policy Statement directed that (1) priority attention be given to facilitating the regulatory and licensing process for the nuclear power industry, (2) commercial nuclear fuel reprocessing be allowed, and (3) work proceed swiftly toward deployment of means of storing and disposing commercial high-level radioactive wastes. The statement also explicitly supported government involvement in demonstrating breeder reactor technology, specifically the Clinch River Breeder Reactor.

industry would not construct without federal support, it was still a demonstration project; and as we noted above, most nonnuclear demonstration projects, particularly many large and expensive synthetic fuel demonstration plants, were eliminated because they fell outside DOE's funding criteria.

Furthermore, the project's payoff had clearly been called into question during the time it was still being supported by DOE. In a July 1982 report,[11] for example, we concluded that breeder reactors may not be economical until after the year 2025 because, among other factors, plentiful and reasonably priced uranium supplies will still exist to power light water reactors (LWR). ERAB also called the CRBR's payoff into question for the same reasons, noting in a November 1981 report that sufficient coal and uranium supplies exist to satisfy projected levels of electrical demand for at least 40 years and possibly well beyond. For these reasons, it recommended "continued research and development on the liquid metal breeder reactor, as well as other breeder concepts, but that demonstration of breeder technology be delayed until a future time."[12]

DOE support for other reactor programs also showed little evidence that the long-term, high-risk, high-payoff criteria were uniformly applied through fiscal year 1984. For example, DOE's longer-term High Temperature Gas-cooled Reactor (HTGR) program was scheduled to be terminated, while its nearer-term LWR R&D programs were scheduled for a 28-percent increase in fiscal year 1984 over fiscal year 1981 appropriations. (This increase reflected a greater emphasis on safety-related research connected with the 1979 accident at the Three Mile Island nuclear power plant.)

Thus, our analysis indicates that the long-term, high-risk, high-payoff criteria did not figure prominently in DOE's nuclear reactor funding decisions through the fiscal year 1984 budget proposal. Rather, (1) DOE continued to support the CRBR, a demonstration project whose payoff had become increasingly questionable in light of stable uranium supplies and (2) the cuts that were proposed in other programs did not appear to target reactor technologies falling outside the criteria.

[11] The Liquid Metal Fast Breeder Reactor—Options for Deciding Future Pace and Direction (GAO/EMD-82-79, July 12, 1982), p. 15-23.

[12] Federal Energy R+D Priorities, Energy Research Advisory Board (DOE/S-0031, Nov. 1981), p. 29.

The Criteria Played an Important Role After the CRBR Was Terminated (Fiscal Years 1985-86)

The fiscal year 1985 and 1986 budgets proposed elimination of more breeder reactor work after the termination of the CRBR. In addition, the fiscal year 1986 budget proposed increased funding for LWR programs. In one sense, an increase in LWR funding accompanied by a decrease in longer-term breeder reactor R&D appears to contravene the criteria. However, changes within each of these categories indicates that the long-term, high-risk, high-payoff criteria played an important role in establishing budget priorities.

For example, after the Congress terminated the CRBR in fiscal year 1984, DOE noted in its fiscal year 1985 budget request that

> "The revised breeder R&D program will be fully consistent with our national energy R&D policy in that there will be no new Federally-funded demonstration project.... The responsibility for demonstrating breeder reactor technology will now rest with the private sector...."

It then asserted that, rather than orienting the breeder program around the CRBR, and being "driven by rigid 'need and timing' logic and a Federal demonstration program," it would now be reoriented toward "future advanced concepts."

This trend away from shorter-term, demonstration-related work was continued in proposed fiscal year 1986 budget reductions, with the elimination of full scale component testing programs needed to support demonstration projects. The manner in which breeder program reductions changed the program's focus led a 1985 CRS analysis to conclude that the cuts in the breeder program were "the only proposed reductions in nuclear energy that represent a significant programmatic change" that has reoriented the program "from a near-term commercial demonstration program to longer term research on ways to improve the economics of breeder reactors."[13]

The LWR budget began a similar reorientation toward longer-term R&D with the introduction of the advanced LWR program, proposed to be funded at $8 million in fiscal year 1986 (out of a total $61 million for all LWR R&D). The fiscal year 1986 budget request explained that this R&D would focus on new designs to overcome industry problems of "product complexity, high cost, and long construction periods." While relying on existing LWR technology, the program seeks to develop and apply innovative features to smaller LWRs in the 400-600 megawatt (MW) range.

[13] Impacts of Proposed Budget Cuts in Selected Energy Research and Development Programs, Congressional Research Service, (85-588, Feb. 20, 1985), pp. 3-4.

Much of the remaining $53 million in the LWR budget request, however, continued to focus on nearer-term activities such as extended fuel burnup, LWR safety, and licensing reform.

Shift Toward Military Priorities (Fiscal Year 1987)

Proposed funding for nuclear reactor programs, particularly advanced reactor programs such as breeder reactors and HTGRs, changed radically in fiscal year 1987 to reflect a new DOE policy emphasizing military applications of nuclear energy, including those associated with the Strategic Defense Initiative. Citing "increasing space and defense nuclear energy needs, currently anticipated timing for commercial deployment of advanced reactors beyond LWRs, and limited research and development resources," the fiscal year 1987 budget request in advanced reactor R&D proposed to "[shift] from satisfying primarily the needs of the civilian sector for advanced reactors to meeting the space and terrestrial power needs for the military."

This reorientation has led to proposed sharp reductions in longer-term civilian reactor R&D. DOE proposed $50 million for R&D in breeder technology, HTGR, and other advanced reactor technologies, down by 61 percent from the $129 million appropriated for these programs in fiscal year 1986, and still further below funding levels of previous years.[14]

DOE's nearer-term LWR programs were also targeted for reduction, but the reductions were much smaller than those proposed for the longer-term advanced reactor technologies. DOE's proposed fiscal year 1987 LWR budget of $41 million represents a decrease of 15 percent from the $48.2 million appropriated in fiscal year 1986—and most of this reduction reflects the fact that LWR safety-related R&D at the Three Mile Island reactor site was nearing completion. This comparatively smaller reduction reflects DOE's view, as articulated in the fiscal year 1987 budget, that ". . . application of improved 'state of the art' light water reactors represents the most likely path to revitalizing the nuclear power option . . . ."

Thus, the reorientation of the fiscal year 1987 nuclear budget appears to have had less to do with the long-term, high-risk, high-payoff criteria than with meeting defense-related objectives of the administration.

[14]DOE has contended that some of these reductions may be cushioned by the fact that much of the military-related R+D may have some application to the civilian reactor industry. This contention, however, has been largely disputed by scientists, including members of DOE's Energy Research Advisory Board. This issue, and its relationship to the nuclear industry's R+D agenda, is discussed in chapter 3.

Moreover, most of the civilian nuclear reactor cuts spawned by this reorientation came out of breeder, HTGR, and other longer-term programs, rather than the nearer-term LWR programs.

Summary and Conclusions

We found that DOE has generally applied the long-term, high-risk, high-payoff criteria consistently across energy R&D programs since fiscal year 1981, reorienting most R&D activities toward the early stages of the innovation process. The clearest evidence of their use has been DOE's comparatively strong funding of General Science, Basic Energy Sciences, and other budget categories that are inherently long-term and high-risk in nature, during a period in which other programs were substantially curtailed.

DOE has also sought to reduce the fossil, conservation, and renewable energy budgets in line with these criteria. While there have been exceptions to this trend, we have found that (1) demonstration projects, marketing programs, and other activities closer toward product commercialization have been curtailed or eliminated and (2) R&D programs have generally been reduced and reoriented during this period to focus increasingly on activities associated with the early stages of the R&D continuum.

Funding for nuclear reactor programs generally has not emphasized the criteria, however, with DOE's strong support for these technologies insulating nearer- and longer-term programs alike from major budget cuts during the early 1980's. Civilian reactor programs sustained substantial reductions beginning in fiscal 1984, but these reductions were based on other considerations as well as the long-term, high-risk, high-payoff criteria. These included a perceived need to (1) address safety issues associated with light water reactors currently operating and (2) emphasize reactor technologies that satisfy certain military objectives.

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Are R&D Efforts Curtailed by DOE Being Picked Up by the Private Sector?

We have generally found little indication that private industry has picked up much of the energy R&D curtailed by DOE. Several factors are largely responsible, including (1) falling oil prices and flat electric power demand growth, (2) the economic risk of picking up demonstrations and other large-scale activities, (3) lack of a strong industry infrastructure in some technology areas to pursue energy R&D without continued government support, and (4) the long-term, high-risk character of some of the technologies curtailed which, by their nature, are much less likely to be pursued by industry.

In this chapter, we first discuss available data showing trends in private sector energy R&D spending during the time of DOE's budget cuts. This is followed by a more detailed discussion of industry R&D in the fossil, nuclear reactor, renewable, and conservation R&D areas.

Private Sector Energy R&D Has Been Reduced in Recent Years

As an initial step in addressing this issue, we examined available aggregate data on private sector R&D expenditures since the present administration's energy R&D budget cuts began. If the private sector was compensating for reduced DOE funding, private sector funding of energy R&D might be expected to increase. However, while industry energy R&D data are incomplete, available figures concerning major energy R&D performers suggest that DOE cutbacks have usually been accompanied by R&D cutbacks in the private sector. Specifically, data from DOE's Energy Information Administration (EIA) show that

- Energy R&D expenditures by 25 major energy companies (mostly oil companies), increased by only 3.8 percent between 1981 and 1984. When spending for petroleum research is eliminated to reflect alternative technologies, R&D decreased by 17 percent over this period. Furthermore, most energy companies have responded to sharply lower oil prices during 1986 by reducing energy R&D expenditures.
- Major natural gas pipeline companies and privately owned electric utilities have decreased their support for research, development, and demonstration by an average 5.9 percent from 1981 to 1984.
- The Electric Power Research Institute's (EPRI) R&D has been flat in constant dollars between 1981 and 1986, and future plans have been affected substantially by reduced revenue projections.
- The Gas Research Institute, however, has been an exception to this trend. It increased its R&D budget by 104 percent between 1981 and 1986.

Although these figures appear to indicate that the private sector has generally not countered DOE reductions, they provide little information on the relationship between the federal and private sector energy R&D programs, the technologies that may have been affected by DOE reductions, or the impact of these reductions on technology development. Information on these issues requires a more detailed assessment of industry R&D in each major technology area, the subject of the remainder of this chapter.

Fossil Energy

DOE's Fossil Energy program funds R&D in coal, petroleum, and gas. The coal budget accounts for the largest share of the Fossil Energy budget—72 percent in fiscal year 1986—as well as the largest share of the funding reductions—a decline of about $657 million between fiscal years 1981 and 1986.[1]

Private Industry Did Not Pick Up Discontinued Coal Conversion Plants

Our analysis of the Fossil Energy budgets between 1981 and 1986, and information obtained from officials in DOE's Fossil Energy Office, show that most of the funding cuts in the Fossil Energy budget came from the elimination of large demonstration projects for coal liquefaction and coal gasification processes. DOE funding in these areas declined from almost $600 million in fiscal year 1981 to $77 million in fiscal year 1986, with most of the reductions occurring in fiscal year 1982. According to information obtained from DOE, these discontinued projects have not been continued by private industry in the absence of further DOE support.

The largest of these facilities in terms of planned financial commitment were two direct liquefaction demonstration plants ("SRC-1" and "SRC-2") designed to convert coal into clean-burning fuels. SRC-1, which would have cost a net $1.488 billion if completed, was cancelled by DOE before construction after $184 million in federal funds were spent. SRC-2, which was co-funded by DOE, Gulf Petroleum Company, and the governments of Japan and West Germany, was cancelled before construction after DOE spent $70.4 million and Japan and West Germany each spent $28.4 million. In addition to these demonstration plants, several smaller liquefaction pilot plants were completed through the pilot plant stage.

[1]These figures do not account for DOE's Clean Coal Technology Reserve (CCTR), which is funded separately. If the CCTR is included, then the coal budget (1) accounted for 78 percent of fossil energy programs in fiscal year 1986 and (2) declined by $557 million between fiscal years 1981 and 1986.

DOE also cited five coal gasification demonstration plants terminated in the early 1980's.[2] Most were in the conceptual development stage, although DOE had spent over $200 million on them before their termination. None has been continued in the absence of further DOE funds.

The Synthetic Fuels Corporation (SFC) was established in 1980 under the Energy Security Act to share with private sponsors the risks of constructing and operating these types of synthetic fuels plants. Indeed, some of these projects were considered for SFC funding after they were dropped by DOE. However, none succeeded in obtaining SFC financing, and the SFC was subsequently terminated by the Congress.

Reasons Industry Has Not Picked Up These Discontinued Projects

Much of the impetus for developing new processes to produce liquid and gaseous fuels from coal came from the energy shortages of the 1970's and the ensuing price increases for petroleum and other competing fuels. Synthetic fuels were viewed as a potentially attractive alternative to high-priced petroleum and gas, and they relied upon the availability of secure domestic coal reserves as opposed to less reliable foreign energy sources.

Declining petroleum and gas prices of the 1980's, however, changed the economics of these coal conversion technologies dramatically and has made private investment less attractive, particularly in the absence of government support. As stated in a 1985 CRS analysis:

"In view of the abundant supply and reduced demand that characterizes the present energy market, it is not surprising that the private sector has deferred or cancelled plans for more than 90 synfuels plants during the last decade."[3]

The report also noted that conventional energy prices would have to increase, in some cases, several fold in order for these technologies to become marginally attractive for industry.

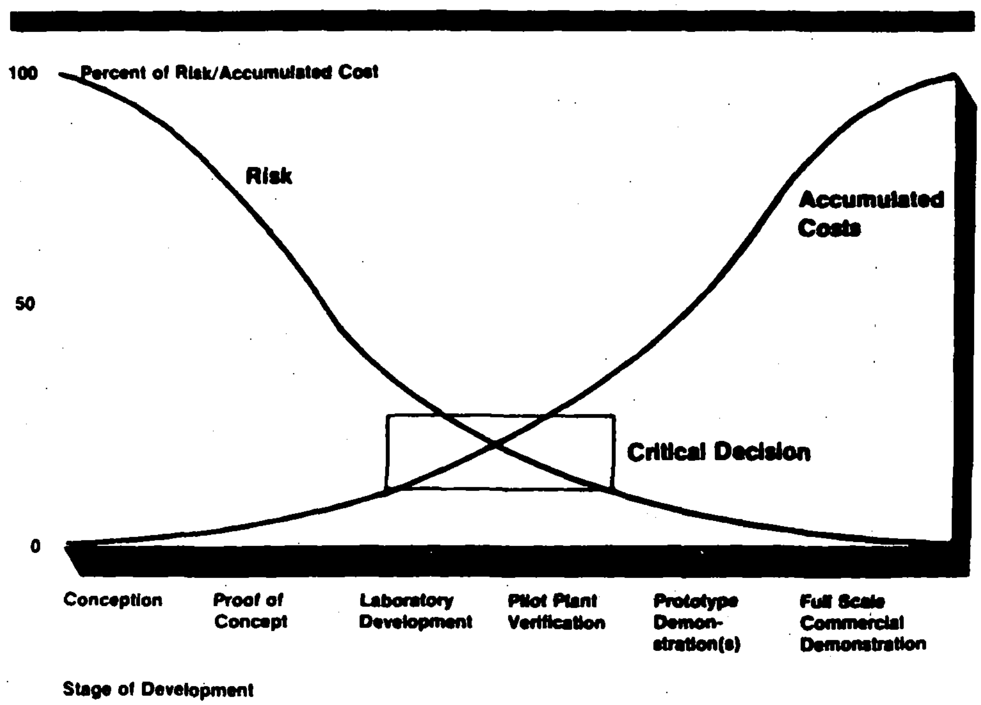
The cost of moving these technologies through the pilot plant and demonstration phases also poses problems. DOE's fiscal year 1987 budget notes that the technological risks are "most defined and predictable" at

[2]These include the CONOCO High-Btu Pipeline Gas, Illinois Coal Gasification High-Btu Synthetic Pipeline Gas, Memphis Light Gas and Water Division Medium-Btu Industrial Fuel Gas, W.R. Grace Gasoline, and Combustion Engineering Low-Btu Utility Fuel Gas demonstration plants.

[3]Handbook of Alternative Energy Technology Development and Policy A Supplement to Accompany Report No. 83-43 SPR, Congressional Research Service (86-36 SPR, Dec. 17, 1985), p. 22.

these latter stages of development. However, while depicting the technology path somewhat differently from that described in chapter 1, figure 3.1 shows that detailed engineering, construction, and other capital expenses cause accumulated costs to increase rapidly at these stages.

Figure 3.1: Technology Cost/Risk Relationships



Source Testimony of Florida Power and Light Co., before the House Energy and Commerce Committee, Subcommittee on Fossil and Synthetic Fuels, February 27 and March 28, 1985.

Various analyses of the issue have also confirmed that the capital investment required to move these technologies beyond the proof-of-concept stage poses additional cost and risk that few companies are presently willing to absorb. A 1981 ERAB report, for example, observed that "the total annual budgets of [EPRI and GRI] . . . are far too small to permit them even to contemplate financing demonstration or first-of-a-kind commercial plants at a billion or more each."[4]

As a result of these additional costs, some industry R&D representatives have asserted that a technology "gap" exists between the proof-of-concept stage and commercialization which, without government support, is

[4]Federal Energy R+D Priorities, Energy Research Advisory Board (DOE/S-0031, Nov. 1981), p. 4.

unlikely to be closed so that technology development can continue. Citing the demonstration phase as "the most crucial" phase of the research process, David O. Webb, Senior Vice-President, GRI, testified before the House Subcommittee on Energy Development and Applications, House Committee on Science and Technology, on June 7, 1984, that

> "What is missing is the federal support for applied research and engineering necessary to demonstrate advanced fossil energy technologies . . . at a scale necessary to extrapolate viable engineering design data and accurately determine process economics."

According to information supplied to us by GRI, which has sponsored considerable research on coal gasification, the organization has not been in a position to increase its funding to a level necessary to pick up discontinued DOE pilot plant and demonstration work. To the contrary, as DOE support for GRI's surface coal gasification research decreased by 88 percent between 1980 and 1986, GRI funds for this research also decreased by 55 percent during the same period.

Thus, coal conversion pilot and demonstration plants discontinued by DOE have generally not been picked up by private industry. Among the primary reasons are (1) the relatively low cost of competitive conventional fuels such as crude petroleum and natural gas and (2) the economic risk for private companies and R&D organizations in spending the billions of dollars often needed to demonstrate the commercial viability of an emerging coal conversion technology.

To some extent, the technology developed at these facilities may have been applied elsewhere, thereby contributing to continued improvements and expanding the R&D knowledge base. DOE officials pointed out to us, for example, that lessons learned from the coal gasification demonstration projects cited above contributed to the development of the Great Plains Coal Gasification Plant, which produces gas from coal on a commercial scale. Two similar examples of continued progress were cited in DOE comments on a draft of this report. (See app. II.) Generally, however, the elimination of planned demonstration plants can be expected to lengthen the time to commercialization for such technologies. This is particularly true in the case of liquefaction, for which construction of the first U.S. large-scale plant has not yet begun.

Electric Utility Applications of Coal

Electric utilities account for about 83 percent of the nation's coal consumption. Research sponsored by both DOE and the electric utility industry has emphasized new technologies to burn coal more efficiently and in a more environmentally acceptable manner.

Generally, we found that federal funding for these technologies has fared better than funding for coal conversion technologies because the Congress has restored a higher portion of the cuts sought by DOE in this area. This is particularly true in light of congressional funding for the CCTR, which is expected to support several projects related to utility coal use. The final outcome has been reduced funding over time, but not to the extent sought by DOE.

For example, steep cuts were sought in DOE's fuel cells program, but funding for that program actually increased by 6 percent between fiscal years 1981 and 1986. Similarly, funding for coal combustion systems declined by only 23 percent during this period, despite the fact that DOE had sought reductions of as much as 83 percent below the fiscal year 1981 level.

Impact on Private Sector R&D Related to Utility Coal Use

To determine the impact of this reduction/restoration funding pattern on private sector R&D related to utility coal use, we contacted officials at organizations most heavily involved in this type of R&D, including EPRI, utility companies, and major utility equipment manufacturers. Our review of EPRI program plans and interviews with program managers showed that EPRI has benefitted from congressional restoration of funds deleted by DOE. For example, coal-related projects identified in a 1981 EPRI report as "at risk because of changing federal funding policies" have either been completed with continued congressional support, are continuing because the Congress restored funding, or have continued to receive DOE support in annual budget proposals.

Nevertheless, problems in EPRI's ability to pick up discontinued R&D in the future may increase for two reasons. First, growing interest in near-term improvements to existing power plants by electric utilities has led EPRI to reorient its research more toward meeting short-term industry needs, such as extending the lifetime of existing electric power plants, and deemphasizing intermediate and long-term R&D related to future generation technologies. This change in priorities could make it more difficult for EPRI to pick up intermediate and long-term technologies discontinued by DOE. Second, EPRI has sustained unexpected cuts in its own

R&D budget, which, according to its 1986 R&D Program Plan, will lead to the delay or elimination of some of its ongoing R&D programs.

Our interviews with the other primary R&D performers in this area suggest that they too would not compensate for future DOE R&D cuts. Specifically:

- Utility companies' R&D tends to be specific to their own operations, and generally not geared toward the type of R&D sponsored by DOE and EPRI that has industrywide application. Furthermore, as ERAB and others have pointed out, electric utilities, as members of a regulated industry, have poor incentives to conduct R&D because their rates of return generally cannot capture the costs associated with the risk of the research.
- Major utility equipment manufacturers' R&D has been affected substantially by projections of low oil prices and low electric demand growth. These views are consistent with the finding of the OTA report, cited above, that "... with the decline in new equipment orders in recent years, manufacturers are less likely to commit R&D to new products for which strong markets are not assured."[5]

Thus, while DOE cutbacks in this area have so far been cushioned by congressional restoration of funds, private organizations are likely to find it difficult to compensate for future DOE reductions.

Petroleum and Gas R&D

Although the largest Fossil Energy cuts in the past 6 years occurred in the coal budget, petroleum and gas programs also sustained reductions. DOE's petroleum R&D budget declined from about $58 million in fiscal year 1981 to about $29 million in fiscal year 1986. The impact of these cuts on private sector R&D and on technology development, however, has been smaller than in the case of coal for at least two reasons.

- Unlike coal research, which has depended heavily on government funding, petroleum research has been overwhelmingly supported by the petroleum industry and has therefore been less affected by DOE budget cuts. For example, petroleum R&D expenditures by 25 major energy producers (most of which are oil companies) totaled about $1.3 billion in 1984 (the last year for which such DOE data were available), compared to about $30 million appropriated to DOE during the same year.

[5]New Electric Power Technologies: Problems and Prospects for the 1990s, Office of Technology Assessment, July 1985, p. 295.

- Petroleum industry R&D has tended to be conducted more independently of the federal energy R&D program than has been the case for coal. Our contacts with 12 major petroleum companies in the nation showed almost unanimously that their research agendas are set independently of, and are relatively unaffected by, the federal program.

  This does not suggest, however, that petroleum research will receive the same level of industry support in the future that it has in the past. As noted earlier, lower oil prices have led many oil companies to sharply reduce their R&D efforts, particularly in longer-term enhanced oil recovery methods and other technologies without short-term payoff. Accompanying these cutbacks have been sharp reductions in oil company R&D staff and technical expertise.

  DOE's R&D funding for enhanced gas recovery declined more steeply than for petroleum, from about $31 million in fiscal year 1981 to about $8.5 million in fiscal year 1986. Testifying before an appropriations subcommittee in April 1985, David O. Webb, Senior Vice-President, GRI, said that DOE cuts in near-term R&D forced GRI to "cancel or defer some of its own projects with a longer-term payback and concentrate its limited resources on projects with a more immediate return to the industry and ratepayers." According to Webb, GRI reoriented its research from about 40 percent near-term work in 1981 to about 80 percent in 1985. Information supplied to us by GRI asserts that, as a result of this reorientation, the majority of its mid- and long-term research in areas such as gas hydrates has been abandoned and has been pursued (albeit at reduced levels) by DOE only through continued support of congressional committees.

Fossil Energy Technologies—a Summary

The greatest impact of Fossil Energy budget reductions on industry's fossil energy R&D has been the loss of large coal conversion demonstration projects. Termination of these projects has contributed to delays in technology development, particularly in the case of coal liquefaction, for which the first large-scale demonstration facility has yet to be constructed. In other areas, such as utility-related applications of coal and natural gas research, congressional restoration of funds deleted by DOE has kept many affected industry research programs alive, albeit at reduced levels. Future loss of government funding for some of these technologies would likely delay technology development because (1) private sector organizations have generally become less able or willing to perform R&D under current economic conditions (particularly low oil and gas prices) or (2) the technologies may be too far away from commercialization for the private sector to support on its own.

Nuclear Energy

As noted in chapter 2, the civilian nuclear reactor R&D budget has generally fared better than nonnuclear technologies over the past 6 years but has recently sustained substantial cutbacks.[6] Most of the R&D curtailed by DOE has been long-term research related to future generations of reactors. We found that little of this R&D has been picked up by the private sector. Rather, the nuclear industry has devoted an increasing share of its resources to nearer-term research, largely because of projected reliance on existing light water reactors well into the next century. Furthermore, a portion of the industry infrastructure supporting the capability to do R&D on breeders and other advanced reactor technologies has been disbanded, making it potentially more difficult for industry to carry on this type of work in the future.

Advanced Reactor R&D Accounts for Most of the DOE Cutbacks

The nuclear reactor programs involving most R&D expenditures, and which have sustained the largest budget reductions during the past 6 years, are those for advanced reactor technologies, particularly breeder reactors. Funding for R&D in advanced reactor technologies declined by several hundred million dollars between fiscal years 1981 and 1986, while research related to light water reactors, for example, increased from about $41 million to about $48 million.

Little Advanced Reactor R&D Curtailed by DOE Has Been Picked Up by Industry

The government and industry officials we interviewed agreed that the nuclear industry has had little incentive to compensate for decreases in DOE's advanced reactor R&D. As we noted in chapter 2, continued low prices for uranium, caused primarily by low demand for nuclear power in the United States, delayed the time when breeder reactor and other advanced reactor systems that rely less heavily on uranium as a fuel might become economically competitive. This delay has led to the virtual elimination of an advanced reactor market in the United States and, therefore, to industry's lack of interest in undertaking R&D in this area.

The clearest example of this outcome is the lack of a successor for the CRBR. Along with the elimination of this project has gone a portion of the

[6] This discussion focuses on the portions of the nuclear budget related to reactor safety and development. Reactor safety and development accounts for the overwhelming share of DOE's nuclear-related R+D expenditures.

industry infrastructure involved in this research. For example, in response to follow-up questions to May 1986 testimony before a Senate Subcommittee, Westinghouse Corporation's General Manager for Advanced Energy Systems stated that advanced reactor program staffing has declined by about 2,000 people (64 percent) between fiscal years 1981 and 1986, and asserted further that this decline "is resulting in an irreplaceable loss of technological capability" for the United States. Similarly, General Electric Company has experienced staff reductions. General Electric is presently designing modular breeder reactor designs with DOE funds, but its total research effort in this area has been substantially reduced from that of past years.

Industry Reoriented Its R&D Away From Advanced Reactors to Meet Near-Term Objectives

One reason for the general disinclination by the nuclear industry to remain in advanced reactor R&D is its perceived need to focus limited R&D resources on near-term needs of current-generation light water reactors. DOE's Nonproliferation Alternative Systems Assessment Program explained in 1980 that

> "The overiding concern in the commercial sector now is assuring that the existing nuclear technology remains a viable competitor and that the underlying industry infrastructure remains intact. Questions regarding which new nuclear technology to pursue are of lesser interest."[7]

EPRI's nuclear reactor R&D agenda reflects this reorientation. According to its 1985-1989 Research and Development Program Plan,

> "The conditions governing nuclear power generation in the U.S. require that the EPRI-supported R&D predominantly emphasize the economic improvement of the present operating plants and the timely completion and operation of the plants under construction."

The plan notes that EPRI-supported R&D will emphasize improved plant availability, component and system reliability, the safety and efficiency of operation, and ways to extend the lifetimes of existing plants.

The findings of an ERAB survey of nuclear industry R&D performers (including four reactor vendors, seven architectural engineering firms, and six utilities) are consistent with this increased focus on near-term LWR research. ERAB's data "confirms that most work relates to the present generation of plants, some work addresses evolutionary new

[7] Nuclear Proliferation and Civilian Nuclear Power: Report of the Nonproliferation Alternative Systems Assessment Program, Vol I: Program Summary, U.S. Department of Energy (DOE/NE-0001/1, June 1980), p. 75.

designs, but little work supports innovative longer-term possibilities."[8] It adds that most of the R&D is devoted to technical areas included in reactor safety. Research is also concentrated on improving the reliability of the present plants, in parallel to (and often jointly with) the EPRI program.

Moreover, the 1986 Chernobyl reactor accident in the Soviet Union has reinforced this emphasis on near-term safety issues related to existing power plants. EPRI, for example, has expanded its source-term research, examining data from the Chernobyl accident to analyze the behavior of radioactive fission products during a severe reactor accident. Other R&D by EPRI and reactor vendors, initiated or continued as a result of the Chernobyl accident, has included safety issues such as research on the health effects of radioactive particles during an accident.

Nuclear industry experts have warned that the United States' reduced investment in advanced reactor R&D may have serious consequences for its long-term competitive position in nuclear technology. ERAB's Advanced Reactor Development Subpanel asserted in an October 1986 report, for example, that ". . . the national research establishment has been allowed to deteriorate and the U.S. has given up its leadership in advanced reactor development to other industrialized nations."[9] It stated that this may ultimately "force the U.S. to import commercial nuclear technology and skills" in the future.

Industry Would Likely Pick Up Few of the Militarized Nuclear Programs in the Fiscal Year 1987 Budget

The fiscal year 1987 nuclear budget proposal would have continued the trend toward reducing the nuclear reactor budget but would have also reoriented much of the remaining R&D to meet military objectives. As we noted in chapter 2, DOE has asserted that some of these military uses would also promote advanced reactor development in the commercial industry. However, as discussed below, industry representatives and technical experts suggest that few of these militarized programs have significant application to the civilian reactor needs.

In response to questions by the Senate Committee on Energy and Natural Resources in February 1986, DOE noted that "although the ultimate reactor designs are different, we do see some commonality between the

[8] Light-Water Reactor Research and Development, Energy Research Advisory Board (DOE/S-0035, May 1985), p. 39.

[9] Advanced Reactor Development, Energy Research Advisory Board, Civilian Nuclear Power Panel, Subpanel II Report (Oct. 1986), p.1.

civilian and defense programs in terms of technology and the sharing of the test facilities and human resources." Specifically, DOE cited the following aspects of the military program that could have civilian application:

- military applications in the multimegawatt range of generating capacity—from 100 to 1,300 megawatts—for powering ground-based Strategic Defense Initiative (SDI) systems. According to DOE, these SDI systems are intended to "rapidly power up for durations of a few minutes or longer . . . ."
- Ten MWe electric reactors, planned for military bases under the SDI program, which, according to DOE, could be adaptable for applications such as industrial cogeneration or power for remote locations.
- Space power requirements and technology applications, including development of high temperature fuel, coolant and materials technology as well as light weight, compact shielding, and remote instrumentation and control concepts.

However, representatives of major reactor vendors have stated to the Congress and to us that little of this military research would directly apply to long-term civilian technology development, although some aspects could have civilian benefit. The Westinghouse testimony cited earlier noted, for example, that "If financial resources are allocated to the military areas at the expense of the civilian area, the civilian research goals will not be met." It noted, however, that test facilities could accommodate military and civilian uses without conflict.

The October 1986 report by ERAB's Advanced Reactor Development Subpanel generally supported these assertions. While citing some instances where the military research could benefit civilian reactor development, it concluded that

> "The chances of any significant benefit coming to the civilian program from this is sufficiently small that such a transfer of funds is equivalent to reducing the civilian nuclear power plant development budget by that amount."

Specifically, the report explained that DOE's advanced reactor test facilities, proposed to be funded at $122 million in fiscal year 1987, could be of substantial value to the military in meeting its testing needs, but that "it is not clear that any reverse benefit would accrue to civilian advanced reactor development." As a result, the Subpanel recommended "strongly" that funds from the SDI budget be provided to fund the military application testing in these facilities.

Thus, little of the military-related nuclear R&D in the fiscal year 1987 budget appears to have relevance to the civilian reactor industry, making it unlikely that the industry would later continue this work to meet civilian reactor needs.

Renewable Energy

Renewable energy technologies involve the conversion of nonfinite or replenishable energy sources such as the sun, wood, water, and wind, into conventional uses such as electricity; heating, cooling, and lighting of buildings; and fuels. The major renewable energy technologies discussed here are photovoltaic, solar thermal, passive and active solar heating and cooling, wind, and geothermal energy.

Although the diversity among renewable energy technologies makes it difficult to generalize across technologies, we have identified a variety of factors that have affected industry's ability and inclination to pursue R&D in general, and R&D curtailed by DOE in particular. These include: the existence of a stable industry with the resources to perform research; tax policies; the price of and demand for conventional energy sources; and the Public Utility Regulatory Policies Act of 1978 (PURPA), which requires electric utilities to purchase power from nonutility small power producers at reasonable prices.

The extent to which these factors have affected industry R&D (including R&D that has been curtailed by DOE) is discussed below for major renewable technologies. The first two in particular—photovoltaics and solar thermal technologies—illustrate the contrast in renewable industries' ability and willingness to invest in R&D in the wake of DOE budget cuts.

Photovoltaics

Photovoltaic (PV) energy systems generate electricity directly from solar radiation. The basic elements are photovoltaic cells, which are electrically and physically linked together. Between fiscal years 1981 and 1986, DOE support for PV dropped from $151.6 million to approximately $40.7 million, with the largest cuts occurring between 1981 and 1982. Despite this 73-percent reduction in federal support and significant competition from overseas, however, the U.S. PV industry today has increased its R&D because of the technology's commercial promise, favorable tax treatment, and other factors.

In a 1982 report,[10] we concluded that DOE cutbacks would be likely to delay PV development and reduce U.S. leadership in the area. This has been borne out to some extent, with declining DOE R&D support (among other factors) contributing to an erosion of the United States' once-dominant position in PV technology. The U.S. share of the world PV market declined from 75 percent in 1980 to 47 percent in 1984, according to the Solar Energy Industries Association.[11] During the same period, Japan's share increased from 15 percent to 36 percent.

Nevertheless, citing the "tremendous potential" of the long-range PV market, we also stated that most large firms would be likely to maintain their R&D efforts and that technological advances would be likely to continue despite DOE R&D cutbacks. This, too, appears to have been borne out in subsequent years. While some small PV companies have gone out of business, new companies have entered the market. In addition, the companies involved have shifted increasingly toward firms that are owned or dominated by oil companies and other major corporations. Thus, the U.S. industry presently has a solid base from which to support R&D, spending $85 million on R&D in 1984, according to the Renewable Energy Institute.[12]

A 1985 OTA analysis attributes much of the progress of the U.S. PV industry to favorable tax treatment.[13] Federal energy tax credits were established by the Energy Tax Act of 1978 (Public Law 95-618) and were expanded by the Crude Oil Windfall Profit Tax Act of 1980 (Public Law 96-223). According to the OTA report, "As direct Federal support declined, indirect support for PV through tax incentives increased during [the early 1980's] and strongly influenced the rate of progress in the industry." Various state tax incentives, and PURPA requirements that PV and other small, independent power producers be guaranteed a reasonable rate for their electricity, also contributed to stimulating the PV industry.

[10] Probable Impacts of Budget Reductions on the Development and Use of Photovoltaic Energy Systems (GAO/EMD-82-60, Mar. 26, 1982), p. 15.

[11] Energy Innovation: Development and Status of the Renewable Energy Industries, 1985, Solar Energy Industries Association (Washington, D.C.: May 1986), p. 264.

[12] Annual Renewable Energy Technology Review: Progress Through 1984, Renewable Energy Institute (Washington, D.C.: 1986, p. 202.

[13] New Electric Power Technologies: Problems and Prospects for the 1990's, Office of Technology Assessment, July 1985, p. 255.

Concern Over PV's Future

As a result, the PV industry has continued and even accelerated its R&D efforts despite DOE R&D cuts, although the pace of development may have been delayed. However, concern among analysts in the government and the private sector over the industry's future investment in technology development has stemmed from (1) the expiration of renewable energy tax credits at the end of 1985 and (2) the recent sharp drop in oil prices.

These analysts have asserted that the loss of tax credits could have affected some markets for PV cells, reduced industry investment, and delayed commercialization of PV systems. OTA concluded, for example, that "The magnitude and relative importance of different market segments, and the character of the industry itself, will depend heavily on whether or not the [tax credit] is extended beyond 1985."[14] These business tax credits, however, were extended in tax reform legislation passed by the Congress in 1986.

However, our interviews with representatives of PV firms indicate that the recent sharp drop in oil prices has also affected the prospects for future PV R&D. Oil companies, which conduct much of the PV research in the United States, have generally responded to lower oil prices in part by cutting back their PV and other R&D programs to reduce costs. At the same time, inexpensive oil has made PV systems less competitive with conventional energy sources. PV representatives indicated to us that their programs will proceed under constrained budgets and delayed time frames.

Nevertheless, analysts still expect PV to receive comparatively strong support because it is viewed as a promising and potentially profitable technology. It is this support from established companies, as well as the availability of energy tax incentives, that explain industry's comparatively strong commitment to PV R&D in the wake of reduced DOE support.

Solar Thermal Technologies

Solar thermal technologies convert sunlight into thermal energy that can be used to generate mechanical and electrical energy, provide industrial and agricultural process heat, or produce chemicals and fuels. While direct federal support for solar thermal systems rose rapidly in the 1970's, DOE support for these technologies was reduced from $138.3 million in fiscal year 1981 to $25.9 million in fiscal year 1986. Moreover, as

[14] New Electric Power Technologies, p 255.

we noted in chapter 2, the focus of remaining activities has shifted from feasibility demonstrations to long-term, high-risk R&D.

While the current status and prospect of solar thermal technologies varies somewhat, industry and government studies agree that their development would likely be delayed considerably without DOE R&D support or indirect subsidies through tax credits. To date, poor prospects for a near-term return on investment have discouraged the private sector from filling the void created by DOE's reduced support for solar thermal R&D. The number of key firms has declined from about 65 to 35 between 1983 and 1986, according to one industry estimate.[15] Many of the firms that have dropped out are large aerospace and energy companies. Many of the remaining ones are small, new, and not as diversified.

Solar thermal central receivers, which account for roughly half of the DOE Solar Thermal budget, represent a case in point of a technology that will have difficulty in making significant progress without DOE support. ERAB's Federal Role Panel, for example, noted in its 1983 report that while DOE has spent considerable funds on development and demonstration of central receiver systems, they are

> "unlikely to be commercialized unless the government follows through by funding the operation of major demonstration projects . . . . Industry will be unwilling to invest in commercial plants until such data is collected and made available. Therefore, a federal role is essential to ensure transfer of the technology."[16]

The ERAB prognosis has so far proven correct. Analysts in the private and public sector have stressed the need for a commercial-scale demonstration central receiver plant to overcome cost and performance uncertainties surrounding the technology. However, private efforts to finance three such plants, ranging in size between 30 and 100 MW, have been unsuccessful. DOE officials told us that the federal government will not support such activities, citing the prohibitively high cost of such projects ($300-$500 million for a 30 MW plant) and DOE's budget constraints. Rather, DOE's program has been reoriented toward reducing the cost and risk associated with system components.

[15] Energy Innovation: Development and Status of the Renewable Energy Industries, 1985, Solar Energy Industries Association. (Washington, D.C.: May 1986), p. 128.

[16] The Federal Role in Energy Research and Development. Energy Research Advisory Board (DOE/S-0016, Feb 1983), p. 20.

Solar Building Energy Systems

Solar Building Energy Systems includes two broad technology areas: passive solar, and active solar heating and cooling. DOE support for these programs declined by 89 percent from $73.3 million in fiscal year 1981 to less than $8.2 million in fiscal year 1986.

Passive Solar

Passive solar technology includes strategies to design and construct buildings in order to make the best use of the sun's energy, thereby reducing the need for conventional fuels. One factor that has inhibited private sector R&D in this area is the diversity and fragmentation of the building industry. It consists of architects, designers, and builders, as well as component and material suppliers. This diversity makes it difficult for any single company to afford R&D. ERAB's Federal Role Panel noted, for example, that because the building industry is "highly fragmented," it is "not capable of carrying out significant R&D."

Solar energy industry representatives have also emphasized the problems associated with this diffuse industry infrastructure. According to the Solar Energy Industries Association (SEIA), because passive solar research consists primarily of new building designs rather than a product, there is no industry focusing on these solar technologies. Consequently, advancement of the technology depends heavily on federal funding, and the amount of DOE support has a direct impact on progress.[17]

Other problems inhibiting private sector R&D in this area have been stable conventional energy prices, which reduce the need for passive solar technologies, and the absence of renewable energy tax credits for passive solar applications.

Active Solar Heating and Cooling

Active solar heating and cooling technologies involve the use of solar collectors to convert the sun's energy into heat for domestic water heating, space conditioning, industrial process heating, and other purposes. Historically, technology development in this area has depended heavily on DOE support, with most products on the market traceable to DOE programs.

Since the early 1980's, cutbacks in DOE support have been accompanied by falling prices for competing conventional fuels, which, according to

[17] Energy Innovation. Development and Status of the Renewable Energy Industries, 1985 (Volume I), Solar Energy Industries Association (Washington, D.C.: May 1986), p. 114.

DOE and industry officials, has caused the industry to contract substantially since its peak in 1981. The expiration of residential energy tax credits (which were not extended in 1986 tax reform legislation) also hurt the industry because much of its business relied on residential applications. Most important, many of the larger companies have since left the industry. SEIA reports, for example, that only a handful of the remaining companies presently perform R&D, and that many do none at all.[18]

Thus, as was the case with solar thermal technologies, active and passive solar technologies have generally depended on DOE more than other industries, such as PV, and have therefore felt the impact of lost DOE R&D support more keenly. Loss of such support, combined with comparatively low conventional energy prices, appears to have left the passive industry stable but stagnating and the active industry in a state of contraction.

Wind Energy

DOE support for wind energy systems declined by about 68 percent, from $77.5 million in fiscal year 1981 to $24.8 million in fiscal year 1986. Despite these cuts, the wind industry in the 1980's has made major technical innovations that have lowered production costs and increased efficiency and reliability. As a result of these improvements, the cost of electricity generated by wind turbines has been reduced more than tenfold since the late 1970's. OTA reports that these improvements are expected to continue, and that "the cost of electric power from wind turbines, even unsubsidized ones, in high-wind parts of the country may soon be considerably lower than power from many of their competitors."[19]

Despite this record, however, government and industry studies have cited several factors other than DOE R&D support that have made future technology development by the U.S. wind energy industry uncertain:

- Expiration of tax credits in 1985. By stimulating investment, energy tax credits have been a major force in promoting the growth and technological development of the wind industry. Wind energy industry representatives told us that these credits helped greatly to ameliorate the impact of reduced DOE R&D. Without the tax credits, DOE and industry officials

[18] Energy Innovation: Development and Status of the Renewable Energy Industries, 1985, Vol. I, Solar Energy Industries Association (Washington, D.C.: May 1986), p. 3.

[19] New Electric Power Technologies, p. 23.

acknowledge that the rate of technology development will be reduced. Unlike other renewable technologies, these tax credits were not renewed for wind energy during tax reform legislation in 1986.

- Reduced electric power demand growth and lower oil prices. In the wake of reduced electricity demand growth, utility industry acceptance of wind as a major source of power has so far been limited. Falling oil prices could make wind energy less economically viable compared with conventional energy sources.
- Foreign competition. Foreign firms have dramatically increased their share of the American market. European wind machines in 1984 captured nearly 30 percent of the domestic market (compared to 5 percent in 1982), and wind industry officials told us that this trend has continued in subsequent years. This increasingly strong foreign competition may contribute to further contraction of the U.S. wind industry and inhibit its ability to perform R&D.

Thus, in a climate of growing electric power demand, high oil prices, and favorable tax and regulatory treatment, industry advanced wind technology quickly despite DOE R&D cuts. However, changes in these conditions and other factors have left some doubt about the pace of research in the future.

Geothermal Energy

DOE support for geothermal energy R&D declined by 83 percent, from $156 million in fiscal year 1981 to $26.7 million in fiscal year 1986. Our interviews with DOE and industry officials familiar with geothermal energy indicate that some geothermal programs are being pursued by the industry in the wake of DOE R&D cutbacks. However, these officials and various analyses agree that flat electric power demand and declining oil prices have reduced industry's R&D commitment.

Indeed, the reduced profitability of geothermal energy today has lessened the likelihood that industry will risk carrying a relatively mature geothermal technology forward without government support, much less a longer-range technology. A representative of a geothermal trade organization told us, for example, that industry has not moved dry steam fields technology into the next generation (hot water fields) because of a perceived lack of return on investment.

Moreover, as we noted in chapter 2, DOE has phased out almost all of its demonstration and commercialization projects. OTA's 1985 report on new electric power technologies observed that beyond the geothermal demonstration plants already being built or operating, very little additional capacity is planned. OTA adds that

"Should few additional plants be deployed in the next 5 or 10 years, the lack of extensive commercial experience is likely to impede rapid expansion of capacity in the 1990's, since the associated risks may be perceived as too high."[20]

OTA also noted that low oil prices may inhibit petroleum companies, which have been key supporters of geothermal energy development, from taking on future R&D investments.

Nevertheless, the participation of major companies, including oil and gas companies, utilities, large engineering firms, and large industrial firms, exhibits a comparatively sound industry infrastructure that could carry the technology forward in a more favorable economic climate. Indeed, some movement in that direction is evidenced by the geothermal industry's establishment of the Geothermal Drilling Organization to work with DOE in cooperative R&D ventures. The Geothermal Resources Council is also planning to establish a similar organization to coordinate industry/government involvement in reservoir engineering projects.

Renewable Technologies—a Summary

Renewable technologies vary considerably in the extent to which industry has pursued R&D, particularly R&D curtailed by DOE. Key factors are the market outlook for each technology and related issues, such as prices of competing conventional fuels, tax policies, overseas competition, and the existence of a stable industry with the resources to perform R&D.

Photovoltaics is one example of a renewable technology that has moved forward in the wake of DOE R&D cuts. It appears to be an industry with substantial resources behind it and strong commercial prospects. While DOE R&D cuts have probably affected the pace of technological development, the PV industry has continued and even accelerated its own R&D efforts. On the other hand, solar thermal central receivers and active solar heating and cooling are technologies that depend more heavily on DOE for their development. The development of these technologies has been substantially affected by discontinued DOE R&D support.

[20]New Electric Power Technologies, p. 268.

Conservation

According to ERAB's conservation panel, energy conservation can be defined as "those activities that change energy consumption through improved efficiency in use. Conservation is simply another word for efficiency, that is achieving desired results with the least use of resources."

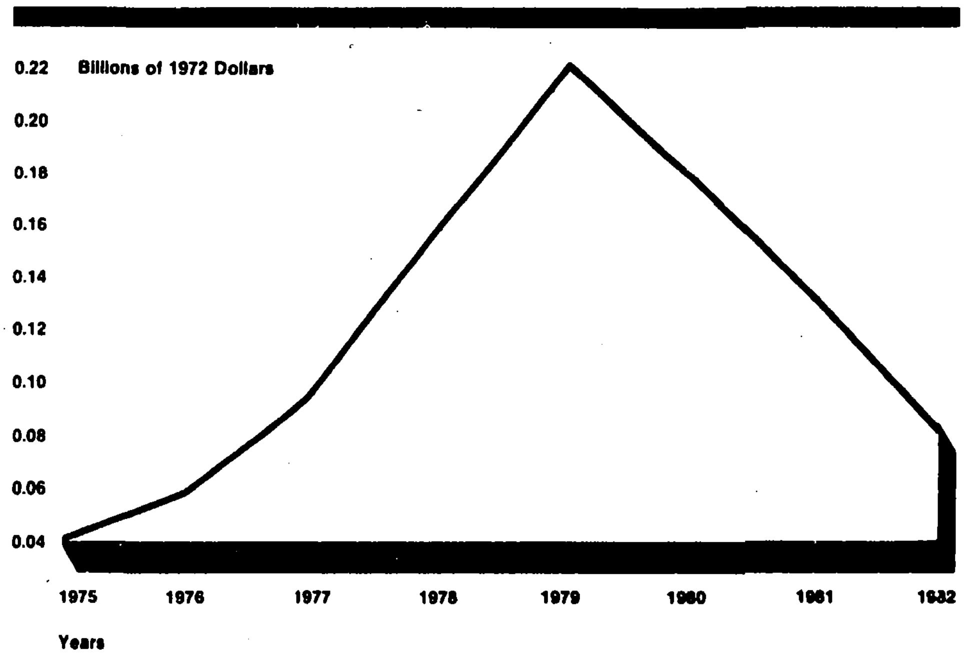
DOE has generally requested sharp reductions in its conservation R&D programs during the past several years, asserting that R&D in this area is largely the responsibility of the private sector. It has noted that high energy prices have already led to substantial improvements in the efficiency with which the nation uses energy, and that sufficient incentives exist for the private sector to continue these efforts. Accordingly, DOE's fiscal year 1987 request of $71.2 million represented a drop of 76 percent from actual fiscal year 1981 appropriations of $292.5 million. However, the Congress has consistently restored much of DOE's proposed reductions, keeping many conservation programs in operation. Actual appropriations therefore decreased by only 42 percent between fiscal year 1981 and fiscal year 1986.

As discussed in this section, several unique characteristics of conservation technologies, compared with the energy supply technologies discussed previously, make it particularly difficult for some industries to undertake this type of R&D (and for analysts to measure the industry's activities). Foremost among these characteristics is the highly fragmented nature of some industries.

Private Sector Conservation R&D Spending Decreased Sharply in the Early 1980's

A 1985 study prepared for DOE found a sharp increase in private industry expenditures on conservation R&D through 1979, followed by a sharp decline in such spending in the early 1980's. (See fig. 3.2.) The study does not explain the decline, although DOE's fiscal year 1988 Energy Conservation Multi-Year Plan suggests that energy price trends are a probable factor.

Figure 3.2: Energy Conservation R&D Expenditures (All Industries)



Source: Battelle Pacific Northwest Laboratory

Such data, along with falling energy prices during the 1980's, cast doubt on whether the private sector has picked up additional R&D in response to federal cutbacks. Nevertheless, the diversity of conservation research requires us to examine each DOE conservation program area individually to identify where discontinued DOE conservation R&D is unlikely to be continued by private industry. These program areas include "multi-sector research" and R&D in the transportation, industrial, and building sectors.

Multi-Sector Research

Multi-sector research involves certain types of R&D that cut across the other three conservation program areas. Its largest component is the Energy Conversion and Utilization Technologies program which, as we noted in chapter 2, DOE has supported strongly because it emphasizes long-term, high-risk, high-payoff research. The fiscal year 1986 appropriation of $25.6 million for multi-sector research was only slightly below the fiscal year 1981 appropriation of $26.5 million.

Nevertheless, DOE proposed $19.9 million for multi-sector research in fiscal year 1987, a reduction of 22 percent from the previous year. DOE's fiscal year 1987 multi-year energy conservation plan casts doubt as to whether the private sector would pick up discontinued research in this area or make any new investments. The plan states,

"The multisectoral technology areas are characterized by high technical risk and a long delay before the economic return on the research investment can be realized . . . . Where the feasibility of a technological advance with significant energy-conserving potential is yet to be established, and before the market can even be defined, there will be no private sector investment at all. Much of the multisectoral research falls into this category."[21]

Thus, while multi-sector research so far has received comparatively strong support, DOE has suggested that it is unlikely that private industry would pick up these types of technologies if they were curtailed in the future.

Transportation

DOE's Transportation programs are intended to provide the technology base for private sector efforts to develop technologies that are either more efficient or are alternatives to those based exclusively on petroleum. The DOE fiscal year 1986 appropriation of $56.6 million represents a decline of 46 percent from fiscal year 1981. This appropriation has supported four subprograms: Vehicle Propulsion R&D, Alternative Fuels Utilization, Electric and Hybrid Vehicle R&D, and Advanced Materials Development.

Experts agree that the automotive industry can generally support its own R&D efforts. For example, ERAB has said in past reports that this sector generally has adequate incentives—a competitive market and a fundamentally healthy industry—to fund a substantial part of its R&D requirements, and that there is consequently a limited need for federal R&D support.[22]

Other experts have also cited the fact that, while many other sectors of the economy are fragmented, the automotive industry's centralized nature contributes to its ability to conduct its own R&D. One analysis, for example, notes that "If we set out to improve energy efficiency in the automobile industry, a great deal can be accomplished by working

[21] FY 1987 Energy Conservation Multi-Year Plan*, U.S. Department of Energy, Office of Conservation, July 1985, p. 172.

[22] The Federal Role in Research and Development, p. 19, and Guidelines for DOE Long Term Civilian Research and Development, Vol. V: Energy Demand (DOE/S-0042, Dec., 1985), p. 31.

directly with a few manufacturers in Detroit."[23] Representatives of the three major automakers also acknowledged to us that the centralized nature and relatively larger resources of the transportation sector generally make it easier for the industry to perform conservation R&D that has technical and commercial promise. They noted, however, that the pace of their research in such areas as methanol and electric vehicles has been affected by declining oil prices.

Industrial Conservation

Funding for Industrial programs in fiscal year 1986 was $40.1 million, down 42 percent from the fiscal year 1981 appropriation. These funds support R&D in the Waste Energy Reduction, Industrial Process Efficiency, Industrial Cogeneration, and Implementation and Deployment subprograms.

Several factors make it difficult to identify either energy conservation R&D performed by the industrial sector or the extent to which discontinued DOE conservation R&D would be picked up by this sector. The industrial sector is diverse, consisting of energy resource companies, electric utilities, industry associations, manufacturers of equipment for industrial energy conversion, and other industries. Moreover, company data are uncertain because of definitional inconsistencies on what constitutes "energy conservation R&D." Tax treatment and proprietary interests also affect how individual technology-related activities are classified.

Nevertheless, on the basis of 49 letters from industry representatives and other information sources, DOE's fiscal year 1987 Energy Conservation Multi-Year Plan offers several reasons why some industries may lack either the capability or inclination to pick up many discontinued technologies. Among them:

- Industry acting alone usually does not pursue particularly risky R&D.
- Industry by itself usually does not pursue R&D that would eventually be used by its competitors.
- Industry alone usually does not perform R&D that responds more to the national welfare than to its own. According to the DOE plan, many "slow payback" activities fall into this category, including fuel utilization technology, industrial waste utilization, and materials recycling.

[23]Maxine Savitz and Eric Hirst, "Technological Options for Improving Energy Efficiency in Industry and Agriculture," Energy Conservation and Public Policy, ed. John Sawhill (Englewood Cliffs: Prentice Hall, 1979), p. 110.

- The historically low R&D levels in the energy-intensive process industries have resulted in limited research capabilities within these industries.

Our interviews with representatives of several of the most energy-intensive industries (including the aluminum, paper, cement, textile, and food processing industries) generally supported these points, although they also revealed the diversity of the industrial sector. Representatives of the cement and food processing industries, for example, both stated that conservation R&D has been scaled back in the wake of reduced DOE support and low conventional energy prices. According to the Aluminum Association, however, aluminum companies generally have the facilities, incentives, and the financial ability to perform this type of research.

Overall, then, the disincentives for some industries to "go it alone" without federal support, combined in some instances with reduced savings caused by lower energy prices, suggest that cutbacks in this area may lead to delays in developing some worthwhile technologies following the loss of DOE support.

Buildings and Community Systems

DOE's Buildings and Community Systems program conducts research to advance the technologies that will save energy in residential and commercial buildings. DOE's fiscal year 1986 appropriation of $37.3 million was 59 percent less than its fiscal year 1981 appropriation.

ERAB has repeatedly cited the need for federal support for R&D in this area because it has high potential for energy savings both in improved energy efficiency and conservation of oil and natural gas. But it has noted that there are few incentives for private sector involvement because of the fragmentation of the building industry. In 1983, it concluded that "federal support is necessary if the benefits are to be achieved in a reasonable time period," and recommended a "primary" federal role for R&D in this area.[24]

Another study noted that legal and regulatory barriers could discourage private sector research in this area.[25] According to this analysis, every state, county, and community has its own building codes, zoning laws, tax structures, and utility regulations. Therefore, introducing into

[24] The Federal Role in Research and Development, p. 19.

[25] Savitz and Hirst, pp. 110-111.

building codes standards for energy efficiency is highly complex and problematic.

In a March 1986 hearing, DOE acknowledged that private sector continuation of at least some types of discontinued buildings research was either unlikely or at least had not been determined, particularly for R&D related to district heating and cooling; illumination; windows; and heating, cooling, and ventilation systems. DOE asserted that in other cases, however, there were professional and trade associations that could support research and commercial development of new energy technologies. As an example, it specified several organizations that could pick up discontinued R&D dealing with commercial and residential building systems interactions.

Our contacts with the organizations DOE cited, however, provided little evidence to indicate that they would continue research on building systems interactions if it were dropped by DOE. Most responded that they do not have the capability to pick up this research. Some indicated that individual companies they represent would not be likely to pursue it without DOE support and, in fact, that a portion of their existing cost-shared activities with DOE have been curtailed or cancelled due to the loss of DOE support.

In summary, available data show that conservation R&D spending in private industry decreased during the early 1980's, the same period in which much of DOE's funding for conservation R&D declined. This would appear to cast doubt on whether private industry has picked up additional R&D in response to federal cutbacks. Recent downward price trends for oil and other conventional fuels has further reduced the incentive for many industries to aggressively pursue conservation R&D.

Some industries, however (notably the transportation industry), appear to have stronger capabilities and incentives to perform conservation R&D that has technical and commercial promise. Others (particularly the building sector) have few incentives for private industry involvement largely because their fragmented infrastructure is not conducive to such investments. Conservation R&D in many of these areas is unlikely to be pursued aggressively without continued DOE support, particularly in the present environment of low conventional energy prices.

Summary and Conclusions

We have generally found little indication that private industry has picked up much of the energy R&D curtailed by DOE. Several factors are largely responsible, including (1) falling oil prices and flat electric power demand growth, (2) the economic risk of picking up demonstrations and other large-scale activities, (3) lack of a strong industry infrastructure in some technology areas to pursue energy R&D without continued government support, and (4) the long-term, high-risk character of some of the technologies curtailed which, by their nature, are much less likely to be pursued by industry.

Energy R&D efforts by the private sector may expand in the future as current market conditions (particularly low conventional energy prices) change. However, DOE energy R&D budget reductions have, thus far, contributed to delays in technology development. Moreover, such delays may have also contributed to an erosion of American technological leadership in some areas such as breeder reactor research and photovoltaic energy.

The implications of delayed technology development for U.S. energy security depend on the future price and availability of conventional energy sources. Should energy prices rise relatively quickly and substantially, as they did in past oil supply disruptions, then delays in developing alternative energy technologies could be very costly. On the other hand, such delays may have little effect on U.S. energy security if conventional energy sources remain available at reasonable cost well into the future.

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Request Letter

NINETY-NINTH CONGRESS

U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON FOSSIL AND SYNTHETIC FUELS
COMMITTEE ON ENERGY AND COMMERCE
WASHINGTON, DC 20515

ROOM H2-331 HOUSE ANNEX NO 2
PHONE (202) 226-2500

November 22, 1985

The Honorable Charles A. Bowsher
Comptroller General
U.S. General Accounting Office
441 G Street, N. W.
Washington, D. C. 20548

Dear Mr. Bowsher:

The Subcommittee has been involved in the review of the Department of Energy's policy toward the advancement of clean coal technologies. As part of that review, some Members became concerned that there may be an imbalance in the manner in which the Department applies its Research and Development policy to the various fuel sources.

During the past five years the budget for coal research and development has decreased by over 90 percent. The reduction in coal R&D reflected the Department's implementation of a new energy R&D policy to limit government-sponsored research to "long-term, high-risk projects". Under this policy, short-range research projects and projects involving development and demonstration of technology have been deemed to be more appropriately funded by the private sector.

However, in the intervening years, the Subcommittee has heard assertions from the private sector, the university community and some government agencies, that this policy is not being evenly applied across the various fuels and technologies. There have been numerous assertions that the Administration invokes the long-range, high-risk policy for those technologies which it desires not to fund but does not adhere to that policy for those projects to which it whole-heartedly lends its support. For example, during the same five-year period in which coal R&D funding decreased by 90 percent, funding for nuclear R&D nearly doubled.

The Subcommittee is interested in whether, and to what extent, this may be occurring. I request that the GAO investigate and analyze the application of R&D policy and whether it is being applied fairly across the board. If you should find that it is not being applied evenly, I request whatever documentation you can provide on the degree to which this is occurring.

The Honorable Charles A. Bowsher - 2 - November 22, 1985

A related and equally important question is what has been the effect of this new R&D policy on the development of energy technologies. This is a larger question which we do not expect you to examine in this project. However, it may constitute a follow-on project at a later time. As an initial step in that direction, however, and as a part of the foregoing project, it would be appreciated if you would provide the Subcommittee with information regarding the extent to which the R&D efforts which have been curtailed by the Administration as a result of the new policy have been picked up by private industry.

The Subcommittee would like, at the very least, a preliminary draft report during its consideration of the Administration's Fiscal Year 1987 budget request. If you have any questions regarding this request, you may contact Kevin Walek of the Subcommittee staff at 226-2500.

Sincerely,

Philip R. Sharp
Chairman

PRS:kpw

Comments From the Department of Energy

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Department of Energy
Washington, DC 20585

NOV 2 8 1986

Mr. J. Dexter Peach
Assistant Comptroller General for
Resources, Community, and
Economic Development Division Programs
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Peach:

The Department of Energy (DOE) appreciates the opportunity to review and comment on the General Accounting Office (GAO) draft report entitled, "Energy R&D: Consistency in Applying Funding Criteria and Relationship to Industry R&D," even though the report contains no recommendations.

DOE is in general agreement with the findings presented and the conclusions reached. There are some matters, however, that should be clarified before the report is issued in final form. The clarifications are segregated by the DOE R&D programs to which they apply.

Fossil Energy

There is one area related to "Industry Pick-up of Curtailed DOE R&D" that could be strengthened to avoid potential misinterpretation. It is true that industry did not ultimately complete the DOE synthetic fuels demonstration projects that were formally terminated in 1981. Reasons are noted in the Principal Findings Section and explored in greater detail in the body of the report (pages 35-38). However, in several cases, development of the specific technologies has continued at an aggressive pace. For example, the BGC/Slagging Lurgi technology proposed for the Conoco/High Btu Pipeline Gas Project in Noble County, Ohio, is now being tested at large scale at Westfield, Scotland. The Texaco gasifier, proposed by the W.R. Grace and Co. for an industrial fuel gas plant, has been commercially deployed at the Cool Water and Tennessee Eastman plants.

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Thus, we believe that care should be taken to ensure that readers do not conclude that development of technologies involved in the DOE synthetic fuel plant demonstrations has ceased. One possible change would be to take the sentence in the Principal Findings Section that currently reads "None of these projects has been picked up by the private sector, although some may have contributed to the R&D knowledge base in this area before their termination," and revise it to read "While none of these specific projects has been picked up by the private sector, some did contribute to the R&D knowledge base and/or the private sector has aggressively continued to pursue commercial application of the coal conversion technology originally proposed."

The narrative on page 38 of the report could also be revised to reflect the points made above.

Renewable Energy

An additional consideration in the reduction of renewable energy outlay requirements stems from the fact that R&D sponsored during the 1970's allowed proof of concept for most of the renewable energy technologies as well as the establishment of an industry base. The R&D investment of the 1980's has been focused on the more fundamental and generic issues which represent the principal technical barriers to broadened technology viability.

With regard to the "industry follow-on" discussion of renewable energy in chapter three:

1. It is unclear whether activities deferred by the private sector are either a permanent or direct consequence of DOE decision not to fund additional large scale demonstrations. Industry response may well represent a logical and reasoned response to the major shifts in short to mid-term market signals coupled with a need to resolve remaining technological issues in a laboratory environment. Several instances of reentry of specific commercial entities into renewable energy have occurred over the past decade and may well recur in response to further shifts in the energy outlook.

2. A number of the technological advances and innovations funded originally within the renewable energy program have attracted industry interest in important alternative applications in the economy. Examples include adaptation of geothermal reservoir and drilling technology for gas/oil exploration; photovoltaic influence on conventional solid state devices; and the utilization of advanced power system control and power conditioning technologies within conventional energy systems.

3. The changing global energy economy, coupled with an increasing renewable energy viability in international markets, has attracted foreign commercial competition. The U.S. industry, however, retains its reputation as the scientific and technical leader in renewable energy.

Conservation

The report repeatedly uses budget numbers to suggest the absence of Administration support for conservation programs. It would be more relevant to look carefully at support for non-demonstration, more basic efforts within the programs to see where growth has actually occurred. It should also be clearly indicated in the report that the budget statistics presented by GAO emphasize budget proposals by the Administration rather than actual appropriations.

Funding comparisons between FY 1981 and FY 1986 for the multi-sector program are complicated because of changes in the composition of the program. Therefore budget numbers which are compared on page 59 are misleading. Energy Conservation and Utilization Technologies (ECUT) in FY 1981 was $7.9M and in FY 1986, $19.3M. Earlier in the report the significant growth in the ECUT program was cited but it is not reiterated here. This information would appear appropriate here as well.

The style of discussion for the conservation and renewable energy areas appears to weigh information and actual data somewhat differently. For instance, in discussing industrial energy conservation programs GAO found that one trade organization stated that the companies themselves "generally have the facilities, incentives, and the financial ability to perform this type of research." In the renewables section of the report considerable attention was paid to the percentage of market penetration by foreign companies (e.g. wind). This type of data is not discussed in the conservation sections. This difference in approach should be explained in the report. For example: "Actual data on industry capabilities to undertake R&D or actual R&D expenditures relating to conservation were not gathered as part of this report."

Nuclear Energy

The Executive Summary of the GAO draft report states that, "The fiscal 1987 DOE nuclear energy budget proposed that most remaining reactor work be reoriented to meet militrry objectives." This is an over-statement of the GAO findings in Chapter 3, pages 42-47, with which we generally agree. The fiscal 1987 DOE request for civilian reactor R&D of $90.5M ($41M for Light Water Reactors and $49.5M for Advanced Reactor R&D) is adequate for the remaining civilian reactor work and is higher than the $71.7M requested for Space and Defense Power Systems.

4

We appreciate the opportunity to review GAO's draft report and hope that you will find our comments helpful. We also appreciate the courtesy shown by the GAO staff and officials during the course of this study. Editorial comments have been provided directly to the auditor under separate cover.

Sincerely,

Harry L. Peebles
Acting Assistant Secretary for
Management and Administration

The following are GAO's comments on the Department of Energy's letter dated November 28, 1986.

GAO Comments

1. We had addressed this issue in chapter 3, citing DOE statements that lessons learned from discontinued coal gasification demonstration projects were later used in developing a commercial-scale plant. References to other examples contained in the DOE comments were added to this discussion, and we added language in the executive summary to make it clear that these curtailed projects may have contributed toward progress in ongoing synthetic fuels research. Nevertheless, as stated in chapter 3, our review determined that the elimination of these planned demonstration plants can be expected to lengthen the time to commercialization for such technologies.

2. This comment represents a factual account of historical support for renewable energy R&D and does not conflict with any of our statements. Rather, it is consistent with our own account in chapter 2, which notes that prior programs had supported commercialization and market development efforts, and that renewable energy R&D has been reoriented during the past several years toward longer-term and higher-risk activities.

3. We agree that factors other than DOE funding reductions have been considered in industry R&D funding decisions in this area, and we have made no statements to the contrary. The question we answered, however, was limited specifically to whether DOE's curtailed R&D efforts had been continued, rather than which factors affect all industry renewable energy R&D. In some instances, we found that the market factors cited by DOE, as well as other reasons, have explained why such R&D activities have not been picked up by industry after they were curtailed by DOE.

4. We acknowledge that some of DOE's renewable energy R&D activities may have had some tangential benefit or use outside the area for which they were originally intended. While DOE cited two specific examples, it would require an expansive analysis to determine the scope and nature of such contributions. Rather, we focused our report on the effect of the DOE reductions in the renewable energy areas for which they were intended. Still, we added language in chapter 1 acknowledging that such tangential uses may exist and that it was outside the scope of our review to identify or measure them.

5. We made no statements that conflict with DOE's assertion that the United States retains its reputation as the scientific and technical leader in renewable energy despite increased foreign competition. We did note that in some areas, however, U.S. technological leadership has been eroded by such foreign competition. The extent of such erosion is difficult to generalize for all renewable energy technologies, but appears serious enough in certain instances (wind energy, for example, where the U.S. industry has lost more than half the U.S. market to foreign competition) to threaten U.S. technological leadership.

6. A balanced assessment of the Conservation budget required us to treat all aspects of the budget rather than focusing only on nondemonstration activities. As part of this exercise, we had pointed out in chapter 2 the growth of basic research efforts, such as Energy Conversion and Utilization Technologies, as DOE suggests. Regarding the DOE comment about our emphasis on budget proposals, we emphasized DOE's proposed budgets in chapter 2 as an indicator of DOE funding policy and stated our rationale for doing so in the "objectives, scope, and methodology" section of chapter 1. In chapter 3, however, we emphasized changes in actual appropriations between fiscal years 1981 and 1986 as part of our examination of the effect of DOE R&D funding trends on private sector R&D. This too, was explained in the objectives, scope, and methodology section and noted throughout chapter 3 where appropriate.

7. We noted in chapter 2 that the ECUT program's funding rose by 92 percent between fiscal year 1981 and the fiscal year 1987 proposal. For the purposes of our discussion in chapter 3, however, it is more appropriate to consider funding trends in the entire multi-sector research program rather than to restate the information on funding for the ECUT portion of the program. As we noted in chapter 3, the multi-sector program decreased slightly from $26.5 million in fiscal year 1981 to $25.6 million in fiscal year 1986. Either comparison, however, still supports our observation in chapter 3 that R&D in this area has received strong support compared to other Conservation R&D programs.

8. Our approach in dealing with each technology area was to rely, to the extent possible, on actual data, such as private sector energy R&D expenditures. However, as DOE conservation program staff noted to us during our review, data on such energy conservation R&D expenditures tend to be incomplete and dated. DOE's fiscal year 1988 Energy Conservation Multi-Year Plan, for example, cites estimates in a recent study by Batelle Memorial Institute for this type of data, but the study presents

data only through 1982. Furthermore, the DOE plan acknowledges that "Reported data on energy conservation R&D are relatively uncertain because of differing conceptual definitions of what constitutes 'energy conservation R&D'" and other factors.

9. We agree with DOE and have accordingly amended language in the Executive Summary in response to this comment.

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