**Trends in US Private-Sector
Energy R&D Funding
1985-1994**

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This report has been prepared in response to a set of four questions submitted by the International Energy Agency's Energy Technology Policy Division to the US Department of Energy's Office of Energy Research.

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Summary of Findings

While broad-based data on private sector energy research and development (R&D) in the United States (US) are hard to come by and their reliability are somewhat suspect, the following can be said with some degree of certainty about private sector energy R&D funding in the US over the period 1985-1994 (all financial data are in constant 1987 US dollars):

- From 1985-1994, overall private-sector energy R&D declined significantly from \$3.2 billion to \$1.9 billion, a real decline of 42%. Much of this decline is attributable to large reductions in industry-funded fossil fuel energy R&D, and in particular to large reductions in energy R&D funding by the 25 largest US oil and gas firms.
- This decline in industrial energy R&D is being compounded by current -- and most likely future -- declining federal funding for energy R&D. Total national (industrial and federal) investments in energy R&D declined in real terms by 35% between 1985 and 1994. National investment in energy R&D was \$5.2 billion in 1985 and only \$3.4 billion in 1994.

**US National Investments in Energy R&D 1985-1994,
by funding source**

- Energy R&D accounted for slightly less than 2% of all (public and private) R&D performed in the US in 1994.
- Fossil energy R&D dominates the US private sector's energy R&D investments, accounting for 56-67% of total private sector energy R&D, over this time period.
- From 1985 to 1994, industry funded the majority (between 55-66%) of all US energy R&D. A great deal of variation exists within this overall average, with well over 70% of all fossil energy R&D being supported by industry, while private-sector funding for nuclear energy R&D accounts for less than 26% of the national effort in this area (the remainder comes from the federal government).
- Anecdotal evidence suggests industry is cutting back on longer term, more basic energy R&D, in response to heightened competition in all parts of the energy industry.
- The current restructuring of the natural gas and electric utility industries in the US is hurting the ability of these industries to fund longer term, pre-competitive energy R&D. Moreover, many analysts believe (though the necessary detailed data is not available to prove) that industry is also altering the composition of its energy R&D portfolio shifting it away from supply/production technologies and toward energy end-use technologies.
- Like US industry in general, those US firms performing energy R&D appear to be using cooperative R&D mechanisms to offset some of the decline in overall industrial energy R&D funding and as a way to continue performing some longer term R&D.

The existing US data on private-sector energy R&D funding can be used to address, but not definitively answer, the questions posed by IEA. This analysis relies principally on three data sets (NSF 1996a; EPRI 1996; GRI 1996), but has been supplemented by trend analyses and other existing data.

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Motivation for this Report

This report has been prepared in response to a set of four questions submitted by the International Energy Agency's (IEA) Energy Technology Policy Division to the US Department of Energy's Office of Energy Research. The IEA's questions all center on trends in US industrial energy R&D spending over the decade 1985-1995. IEA has asked all of its member countries similar questions and intends to use the resulting multi-country data set on trends in private-sector energy R&D as basis for discussions at its October 16, 1996, Governing Board Meeting.

This report first describes the principal data sets used with caveats about their shortcomings, then characterizes the context of US R&D spending over the recent past and short-term future. The remainder of the report is organized by addressing each of the four IEA questions. The appendices provide further information.

Caveats

This report's analysis of US private-sector energy R&D is built upon a combination of three primary data sets. The first of these is an official US Government survey of industrial R&D expenditures (NSF 1996a). The other two data sets used in this report are historical funding data from the Electric Power Research Institute (EPRI 1996) and the Gas Research Institute (GRI 1996), two large nonprofit energy research organizations in the United States. Energy R&D data for 1995 are unavailable because of a reporting lag time of approximately 18 months. All data are in constant 1987 (i.e., inflation-adjusted) US dollars, unless otherwise noted (NSB 1996).

Because of the heterogeneity and existing limitations of the data, certain shortcomings and associated caveats should be kept in mind while reading this report:

1. The data in this report on private-sector funding for energy efficiency, renewable energy, and energy utilization R&D probably underestimate true US industrial investment in these areas.
2. Comparisons of changes in energy R&D funding levels from 1985-1994 will be somewhat suspect because of the discontinuity in these data occurring in 1992, when NSF's survey methodology changed.
3. It is difficult — if not impossible — to derive from these statistic insight into the development of specific classes of technologies by US industry.
4. Accounts of US public sector energy R&D data in this report differ from standard published accounts of energy R&D contained in the federal budget.

Readers are strongly encouraged to examine a more detailed explanation of these data limitations in Appendix #1: Detailed Methodology and Data Considerations.

Context

Before examining trends in US private-sector energy R&D investments, it is useful to put these energy R&D figures in context and to consider the prospects for overall US R&D funding over the next few years.

- An estimated \$171 billion dollars was spent on R&D in the US in 1995. Industry was responsible for approximately 60% of this funding and the federal government supported approximately 38% of the national R&D effort. Total US investments in R&D have remained flat since 1991. This has not always been the case in recent years. The average, inflation-adjusted rate of R&D expenditure growth in the US was 8.1% from 1982-1985 and 2.1% from 1986-1991 (NSB 1996).
- The Industrial Research Institute¹ (IRI) says that "the outlook for (future) industrial R&D looks more positive than it has in recent years." IRI predicts that US industrial R&D could rise as much as 6% in 1996. This is the largest planned increase in industrial R&D since 1990 and would represent the first real increase in industrial R&D expenditures since 1991 (IRI 1995).
- On the other hand, projections of future federal R&D funding do not look quite as bright due to bipartisan efforts to balance the US federal budget by 2002. The American Association for the Advancement of Science predicts that efforts to eliminate the federal deficit will result in cuts of somewhere between 19-23% in real federal R&D spending by the year 2002. The distribution of these cuts across federal R&D activities has yet to be determined, but it is clear that some federal agencies and some types of federally funded R&D will suffer more than others.²

IEA Question #1: Are industry (energy) R&D expenditures monitored by the United States Government? If so please, please describe the types of data that are collected.

Yes, the United States Government collects data on private sector energy R&D expenditures. Four government-collected data sets were identified and are described below. It is interesting to note that federal monitoring of private sector energy R&D investments began in response to the oil crises of the 1970s.

- The National Science Foundation funds the Department of Commerce's Bureau of the Census (NSF/Census) to conduct an annual Survey of Industrial Research and Development (NSF 1996a). Biennially, this survey collects data on the private-sectors funding of energy R&D performed by industrial firms with annual R&D budgets of over \$1 million.³ Energy R&D data are presented in two principal forms: (1) by primary energy source (e.g., fossil fuels R&D, nuclear R&D, renewable energy sources R&D, and energy conservation R&D) and (2) by major industrial grouping (e.g., chemicals and allied products, petroleum refining

and extraction, machinery, electrical equipment, aircraft and missiles, and non-manufacturing industries). This NSF/Census data set will be used extensively in this report.

- The Department of Energy's Energy Information Agency (DOE/EIA) collects data on the energy R&D expenditures of the 25 largest energy producers in the US EIA 1996). These "major energy producing" firms are predominately involved in the extraction and refining of petroleum and natural gas.⁴ The energy R&D data of these firms are collected and reported in the following categories: Oil and Gas Recovery, Other Petroleum, Coal Gasification/Liquefaction, Other Coal, Nuclear and Other Energy (e.g., renewable energy). The data contained in this survey of major energy producers' energy R&D funding will be used in this report to complement the NSF/Census data set.
- The Department of Energy's Federal Energy Regulatory Commission (FERC) collects data on the energy research, development and demonstration RD&D investments of investor-owned electric utilities.⁵ FERC asks investor-owned utilities to report RD&D by primary purpose (e.g., various generation technologies such as hydropower, nuclear, gas turbines, renewables; transmission research; distribution research). FERC also asks the electric utilities to report the portions of RD&D performed internally and externally, including contributions to the Electric Power Research Institute. In the past, these data have been published by DOE/EIA in some of its annual reports on the electric utility industry. However, these data are no longer published by DOE/EIA, and therefore these data will not be used in this report.
- FERC also collects data on the energy RD&D investments of interstate gas pipelines.⁶ FERC asks natural gas companies to report RD&D by primary purpose (e.g., pipeline efficiency research; compressor station efficiency research; various storage technologies; exploration, drilling, production research; synthetic gas research). FERC also asks gas companies to report RD&D performed internally and externally, including contributions to the Gas Research Institute. It appears that these data have not been published by DOE/EIA for quite some time, and therefore these data will not be used in this report.

IEA Question #2: How much money did industry spend to support energy technology development⁷ in your country in the following years: 1985, 1993, 1994, 1995⁸?

The following chart and table present data on total private sector energy R&D in the US for the period 1985-1994. (See Figure 1.) Please see Appendix #1 for a description of how EPRI and GRI's funding was distributed into these categories. Estimates for withheld data in the NSF/Census data set were obtained by linearly extrapolating from available data for the previous and subsequent years.⁹

**Figure 1: Total US Private Sector Energy R&D,
by fuel type**

Sources: NSF 1996a; EPRI 1996, GRI 1996.

Millions of constant 1987 US Dollars

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fossil Fuels	\$2,144	\$1,804	\$1,895	\$1,793	\$1,673	\$1,795	\$1,904	\$1,464	\$1,085	\$1,040
Nuclear	\$227	\$147	\$160	\$186	\$107	\$139	\$126	\$158	\$149	\$133
Renewable, Conservation, Utilization	\$332	\$291	\$313	\$302	\$383	\$245	\$406	\$392	\$249	\$224
All other energy	\$481	\$450	\$486	\$481	\$563	\$581	\$401	\$297	\$464	\$465
Total	\$3,184	\$2,692	\$2,853	\$2,762	\$2,726	\$2,760	\$2,838	\$2,311	\$1,946	\$1,861

Sources: NSF 1996a; EPRI 1996, GRI 1996.

Significantly, there was a major change in the level of US industrial funding for energy R&D between 1991-1994. The data suggest that private-sector support for energy R&D dropped by nearly a billion dollars (\$976 million), a real decline of 34% in just these four years. However, due to the discontinuity in the NSF/Census data set (discussed in the Appendix #1) the actual decline may be more modest.

- The only documented change in private sector energy R&D occurred at the major (top 25) oil and gas companies who reduced their energy R&D spending by 30% (\$444 million) between

1991-1994 (EIA 1996). The drivers behind this reduction will be discussed in the last section of this paper.

- Funding for energy R&D at GRI and EPRI stayed the same (GRI) or increased slightly (EPRI) during this period. So changes in energy R&D funding at these two institutions does not help to explain this large downturn in US private sector energy R&D at the start of this decade.
- The only other major factor that helps to account for this decline is the fact that the years 1991-1994 straddle the discontinuity in the NSF/Census data set that was discussed in detail earlier. It appears reasonable to assume that the change in NSF/Census' survey methodology is responsible for a very significant proportion (i.e., a few hundred million dollars) of the \$976 million decline in energy R&D, which can not be accounted for by reductions in the major energy R&D producers energy R&D spending during this period. That is, *it is impossible to tell the true magnitude of the decline in US private-sector energy R&D in the early part of the 1990s.*

Some other points to note about the private sector's funding of energy R&D over this time period include:

- Private-sector energy R&D in the US is dominated by R&D relating to the extraction, preparation and use of fossil fuels. Energy R&D related to fossil fuels accounts for 56-67% of private-sector energy R&D over the period 1985-1994, though it is interesting to note that the percent of the total industrial energy R&D accounted for by fossil R&D has been declining steadily over this time period. It appears that the vast majority of industrial fossil energy R&D is related to oil with significantly less being expended on coal and natural gas (EIA 1996).
- The major industrial groups performing energy R&D in the US are chemicals and allied products (SIC 28), petroleum refining and extraction (SIC 13, 29), machinery (SIC 35), electrical equipment (SIC 36), and aircraft and missiles (SIC 372, 376). It is also important to note that nonmanufacturing industries are performing an increasing share of total energy R&D. US gas pipeline companies and electric utilities, through GRI and EPRI respectively, are also major centers of private-sector energy R&D funding. (See Figure 2.)

**Figure 2: Total US Private Sector Energy R&D
1985-1994, by major industrial group**

Sources: NSF 1996a; EPRI 1996, GRI 1996.

- Over this time period, 55-75% of all US energy R&D was funded by the private sector. However, there is a great deal of variation in this overall average. Well over 70% of all fossil energy R&D is funded by industry, while private-sector funding for nuclear energy R&D accounts for less than 26% of the national effort in this area (the remainder comes from the federal government). It is interesting to note that the major US energy producing firms report that less than 2% of their overall R&D effort is funded by the federal government (EIA 1996).

IEA Question #3: From the experience of your country in working with industry what is the timeframe of their R&D efforts in terms of the expected payback of their investments (e.g., short term 0-3 years, medium term 3-7 years, long term 7-12 years, or very long term beyond 12 years)?

The US government does not collect data that specifically attempt to quantify industry's R&D

investment time horizons. Moreover, neither of the government surveys of private-sector energy R&D used here collect data that are useful in estimating the time horizons of industry's energy R&D investments. Therefore, this report paper *can not* specify industrial energy R&D time horizons. However, anecdotal evidence will be presented that seems consistent with the widely held belief that US industry is shortening its timeframe for R&D investments in response to factors such as increased competition.

Current trends in overall industrial R&D may provide some insight into private-sector energy R&D investment time horizons.

- The Industrial Research Institute (IRI) reports that their members' investments in "directed basic research" declined steadily, as a share of their total R&D effort, during the time period 1989-1994. Many believe that directed basic research represents industry's longer term R&D investments and that a decrease in directed basic research implies contraction of industry's R&D investment timeframe. It is significant to note, however, that in 1996 IRI's members reported they planned to carry out more directed basic research than they did in the previous year, thereby halting the erosion in directed basic research investments that began in 1989 (IRI 1995).
- Furthermore, IRI reports that how industry organizes itself to conduct R&D is changing. Many firms have been shifting the majority of their R&D resources out of central corporate laboratories (long believed to be the home of longer term industrial R&D) and into business unit laboratories (which are believed to be the locus of shorter term, product R&D). For example, corporate level R&D at General Electric has dropped from 75% of the company's total R&D effort to only 25% in the past 8 years. The shift from corporate R&D to business unit R&D has been even more dramatic at Kodak, falling from 85% to 5% (Larson 1994).

With respect to energy R&D-performing firms, the following data and anecdotes are suggestive – but not conclusive proof – of a contraction in industrial energy R&D investment timeframes.

- As the next section will show, recent reductions in energy R&D investment levels at the major energy producing (mainly petroleum) firms appear to be driven by rather near-term factors such as the need to develop new oil and gas reserves and the relative price of oil, implying the bulk of petroleum energy R&D is probably not focused on meeting long term goals, but rather that it is focused on meeting customer needs and maximizing (near-term) returns.
- Many analysts see recent reductions in GRI's and EPRI's R&D investments as a sign these institutions' members, the US gas and electric utilities respectively, are reducing investments in longer term cooperative R&D in an attempt to improve their near-term price competitiveness. GRI and EPRI have long been the home of longer term industrially financed energy R&D related to these industries

It is important to note that even amid these indications that industry is shortening its investment time horizon, private partnerships between firms and with federal laboratories are an increasingly common means of continuing to carry out some high-value, long term R&D. The increase in the

number of industrial R&D partnerships will be discussed in more detail in the next section.

IEA Question #4: How would you describe industry energy technology investment trends over the past ten years?

The most obvious trend is the decline in US private-sector energy R&D expenditures over the past decade. Data contained in this report show that overall private energy R&D declined 42% over the time period 1985-1994, falling from \$3.2 billion to \$1.9 billion. (All financial data are in constant 1987 US dollars.)

Another trend that has emerged over the past decade is that relative contributions made by the public¹⁰ and private sectors to the nation's overall energy R&D effort are changing. Until the early 1990's, industry funded over 60% of the nation's energy R&D. However by 1994, the last year for which data are available, industry supported only 55% of the nation's overall energy R&D effort.

Specific elements within the energy R&D portfolios of the public and private sectors have also changed quite a bit over this time period (see Figure 3).

- Both the public and the private sectors have increased the percentages of their energy R&D portfolios that are directed towards energy efficiency, renewable energy, and energy utilization R&D. Energy R&D in this area has increased from 18% to 32% of all federal energy R&D from 1985-1994, while the private-sector's investments in this area have increased slightly from 10-12%. However, it is important to note that for reasons discussed earlier, data contained in this report on energy efficiency, renewable energy, and energy utilization R&D most likely understate industry's true investment levels in this area; therefore, it is highly likely that energy efficiency, renewable energy, and energy utilization R&D probably accounts for more than 12% of industry's entire energy R&D portfolio.
- The relative emphasis placed on fossil energy R&D by the public and private sectors in their respective energy R&D portfolios diverged over the time period 1985-1994. For the federal government, fossil energy R&D dramatically increased its share of total federal energy R&D, largely due to the Department of Energy's Clean Coal Technology Demonstration Program, from 16% of all federal energy R&D investments in 1985 to 29% of the total in 1994. In contrast, private-sector investments in fossil energy R&D declined, from 67-56% of the total private-sector energy R&D effort from 1985 to 1994.
- Nuclear energy R&D made up a smaller percentage of the public's energy R&D portfolio and remained a minor component of the private sector's energy R&D portfolio over the period 1985-1994. For the federal government, nuclear energy R&D went from 43% of its total energy R&D budget in 1985 to 26% in 1994. In the private sector, nuclear energy R&D remained at about 7% of its total energy R&D effort throughout this period.

**Figure 3 Public and Private Energy R&D Portfolios
1985 and 1994**
funding for energy R&D by primary fuel type

To better understand some of the trends in private sector energy R&D investments over the period 1984-1994, it is necessary to examine in more detail the changes in the private-sector's fossil energy R&D investments over this time period because of the size¹¹ of this investment relative to all other privately-funded energy R&D technology areas and also because of the large decrease that occurred in these investments after 1991. First and foremost, it is important to note the dominance of the 25 largest energy producing firms' energy R&D spending (EIA 1996).¹² For example, in the crucial years 1991-1994 when private sector energy R&D was declining precipitously, the energy R&D investments of these 25 firms accounted for more than 80% of all private-sector fossil energy R&D and more than half of total private sector energy R&D. Energy R&D in these top 25 firms declined steeply from \$1.4 billion (1991) to \$1.0 billion (1994), a real decline of 24%. Possible explanations for this decline in energy R&D funding at these top 25 firms include the following:

- Downsizing of these firms as they restructured and consolidated in an effort to cut costs and improve their competitiveness; for example, overall employment in these firms decreased by 165,000 (20%) from 1990-1994 (EIA 1996).
- Payoffs from previous investments in R&D relating to 3D seismic mapping, horizontal drilling techniques, floating production/storage platforms for offshore fields, and for coal production longwall mining systems have contributed to lower costs of adding reserves, thereby lessening the need for further investments in some exploration- and production-related energy R&D (EIA 1996).

- Privatization of upstream production and (secondarily) downstream refining assets in the Former Soviet Union (FSU) represent enormous opportunities for these US energy producers, but one that will be realized only through the infusion of considerable amounts of capital. Some firms might have cut back on their R&D spending to direct capital to the development of oil and gas fields in the FSU (EIA 1996).

The current restructuring and deregulation of the natural gas and electric utility industries is causing these industries to reduce their energy R&D investments. For example, since GRI's R&D funding peaked in 1992 at \$176 million it has declined to \$131 million in 1996, a real decline of 26% (GRI 1996). EPRI's R&D funding has declined from its peak of \$412 million in 1993 to \$331 million in 1996, a real decline of 20% (EPRI 1996). Many analysts see these cuts as a sign these institutions' members, the US gas and electric utilities respectively, are reducing investments in longer term cooperative R&D (GRI and EPRI have long been the home of longer term industrially financed energy R&D related to these industries) in an attempt to improve their near-term price competitiveness. While the data available for this study are incapable of validating this, many analysts also believe that changes in the US utility sector are causing GRI and EPRI to alter their R&D portfolios to place less emphasis on energy supply and production technologies and more on energy end-use technologies.

Lastly, private industry has dramatically increased its use of collaborative research arrangements for carrying out certain aspects of energy R&D over the past decade. The surge in partnering has been driven by a number of factors, including (1) the passage of legislation in 1980s that actively sought to foster collaborative research and (2) the increasing cost and complexity of developing technologies. Cooperative R&D mechanisms provide industry with opportunities to leverage their declining resources for energy R&D.

- By the end of 1994, there were more than 450 officially registered Joint Research Ventures (JRVs) which allow two or more private firms to perform collaborative R&D (the average number of firms is 13.4). NSF notes that most of the research conducted by these JRVs has been process-oriented (which can often be a way of decreasing the usage of energy and other raw materials). NSF also notes that "environmental research" is the major focus of the JRVs formed in the energy-related industries of petroleum, chemicals, and transportation equipment (NSB 1996).
- From their inception in 1986 to September 1994, more than 1000 cooperative research and development agreements (CRADAs) have been formed between DOE, its laboratories, and private firms to transfer technologies developed in DOE's laboratories to industry. While no statistics exist to show how many of these CRADAs are "energy R&D related," it seems clear some of these are related to the transfer of energy technologies to industry (DOE 1994).
- DOE's Clean Coal Technology Program also demonstrates another way that industry forms partnerships with others to maximize declining energy R&D investments. Since its inception in 1986, the Clean Coal Technology Demonstration Program has resulted in more than \$7.0 billion of public-private investment (non-federal contributions account for 66% of the total) in technologies designed primarily to create new technologies to reduce the release of acid rain pollutants and create energy-efficient technologies that could repower or replace existing

coal-fired facilities (DOE 1996).

- In 1992, the major US automobile makers (Chrysler, Ford and General Motors) formed the United States Council for Automotive Research (USCAR) to coordinate 13 separate cooperative research programs on emissions control, fuel efficiency, manufacturing, and safety-related issues. In the fall of 1993, USCAR and the federal government formed the Partnership for a New Generation of Vehicles, a cooperative research venture designed to create a vehicles with up to three times more fuel efficiency than current models (USCAR 1994).
- The DOE recently initiated its "Industries of the Future" program to develop energy efficient and pollution control technologies in cooperation with the seven most energy- and waste-intensive industries in the US: forest products, steel, aluminum, metalcasting, chemicals, petroleum refining, and glass (DOE OIT 1996).

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1. IRI's member companies represent the 265 largest private sector R&D funders in the US and invest a combined \$55 billion annually in R&D.

2. Testimony of Dr. Albert H. Teich, Director, Science and Policy Programs, American Association for the Advancement of Science, Before the U.S. House of Representatives' Science Committee July 23, 1996.

3. Energy R&D financed by industry but performed by a university or government laboratory would not be captured in this NSF/Census data set.

4. These top 25 energy producers accounted for 52% of total US crude oil and natural gas liquids production, 44% of US natural gas production, and 65% of US refinery capacity.

5. Data on energy R&D from investor-owned utilities is collected via the Federal Energy Regulatory Commissions annual survey, *FERC Form No.1: Annual Report of Major Electric Utilities, Licensees and Other*.

6. Data on energy R&D from interstate natural gas pipelines is collected via the Federal Energy Regulatory Commissions annual survey, *FERC Form No.2: Annual Report of Major Natural Gas Companies*.

⁷ Please note that the question asked by the IEA refers to funding for "energy technology development" which is considered to be a subset of energy R&D. The United States Government collects data on "energy R&D" and not at the more specific level of "energy technology development." Therefore, this paper reports on the private-sector's overall "energy R&D" spending efforts.

⁸ Please note that data for 1995 are not available due to a more than 18-month lag time associated with the collection, preparation, and dissemination of the data obtained from this NSF/Census survey.

⁹ NSF/Census suppressed data for industry funding of fossil fuel R&D; renewable, conservation and utilization R&D, and all other R&D for 1986 and 1987. The Census Bureau (and therefore the NSF) are prohibited from publishing data that may reveal information about individual companies. Therefore, some data elements in the more detailed series are intentionally suppressed. Typically, data are suppressed for two primary reasons: (1) when a small number of companies account for a large percentage of the R&D funds in a given industry, and (2) when more than 50% of the firms in any one category fail to respond to the survey. While data is often suppressed at this more specific level, these suppressed data are included in the overall totals. This practice of suppressing firm-specific data explains why some of the more detailed series on the attached graphs contain many discontinuities, which tends to limit one's ability to perform meaningful temporal analyses for these series.

¹⁰ Once again it is important to note that not all items typically found in published accounts of federal energy R&D funding are included in this report's analysis. Certain energy R&D items that are contained in the Energy R&D (270) Budget Function have been dropped from this analysis since they were judged to not be comparable to private-sector energy R&D investments. Items in the 270 budget function that were dropped for this analysis include R&D related to Biological and Environmental Research, "supporting research", Environmental Restoration and Waste Management, university and science

education, occupational and public health, Environment Safety and Health, Advanced Neutron Source, and multiprogram lab support.

¹¹ It is hard to overstate the relative size of the private-sector's fossil energy R&D investments when compared to all other public and private energy R&D investments. To wit until 1991 the year in which industry started to dramatically cut back its funding of fossil energy R&D, industrial-funding of fossil energy R&D was larger than the combined federal investment in fossil, nuclear, renewable energy and energy conservation R&D.

¹² Energy R&D in these firms is heavily concentrated in energy R&D relating to petroleum (including natural gas); comprising 82-88% of all of these firms' energy R&D expenditures over the time period. Non-petroleum energy R&D is a minor part of these firms energy R&D portfolios; Coal-related energy R&D (3-4% of total energy R&D) and Nuclear, Solar, and Geothermal energy R&D (5-9% of total energy R&D).

Appendix 1: Detailed Methodology and Data Considerations

As noted in the body of this report, the report's analysis of private-sector energy R&D is built upon a combination of three primary data sets. The first of these is an official US Government survey of industrial R&D expenditures (NSF 1996a). The other two data sets used in this report are historical funding data from the Electric Power Research Institute (EPRI 1996) and the Gas Research Institute (GRI 1996), two large nonprofit energy research organizations in the United States. It proved necessary to add in the energy R&D carried out through EPRI and GRI, since the government survey did not include work funded by and carried out by nonprofit entities. For example, energy R&D funded by an investor-owned electric utility but coordinated through EPRI would not show up in the NSF/Census data set.

Because of the heterogeneity and existing limitations of the data, certain shortcomings and associated caveats should be kept in mind when viewing this report's accounts of public and private energy R&D funding from 1985-1994:

The data in this report on private-sector funding for energy efficiency, renewable energy, and energy utilization R&D probably underestimate true US industrial investment in these areas.

Detailed historical data for EPRI's and GRI's energy R&D programs broken out by fuel type (e.g., fossil fuels, nuclear, renewable energy) are not readily available. However, efforts were made to break this funding out as much as possible, and reasonable estimates for fossil energy and nuclear R&D were obtained. The following modifications were made:

- GRI's energy R&D was assigned to this report's category of "fossil energy R&D."
- For 1985-1987, EPRI annual funding for coal R&D is the sum of funding in its Advanced Power Systems and its Coal Combustion Divisions minus \$10 million for renewable R&D. The EPRI annual funding for coal R&D was then assigned to this report's category of "fossil energy R&D."
- For 1987-1996, EPRI annual funding for coal R&D is the funding for its Generation Division/Group, again minus \$10 million for renewable R&D. (Jim Burke, EPRI's former director of renewable energy research, estimates that research in this category was funded at approximately \$10 million annually for 1985-1996.) The EPRI annual funding for coal R&D was then assigned to this report's category of "fossil energy R&D."
- EPRI provided data for its nuclear R&D funding for 1985, 1986, and 1993-1996 only; EPRI funding for nuclear R&D for 1987-1992 was estimated by extrapolating from the data provided. This EPRI nuclear R&D funding was assigned to this report's category of "nuclear energy R&D."

- The remaining EPRI R&D was assigned to this report's "all other energy R&D" category.

However, it was not possible to account for these organizations' funding of renewable energy, energy efficiency, and energy utilization (also known as end-use) R&D. Therefore, this R&D was assigned to an "other energy R&D" category, thereby undercounting EPRI and GRI funding for of renewable energy, energy efficiency, and energy utilization R&D.

Furthermore, the NSF/Census government survey of industrial energy R&D also presents a somewhat distorted view of private-sector investments for renewable energy R&D, energy efficiency R&D, and energy utilization R&D because this survey does not collect energy R&D data from "small R&D performers" (i.e., firms who spend less than \$1 million per year on R&D). The NSF/Census statistics do not capture any of the energy R&D which is performed by small firms. In energy industries likely to be populated by small firms (e.g., renewable and energy efficiency), the NSF/Census data will underreport the amount of energy R&D being conducted in the U.S.

Comparisons of changes in energy R&D funding levels from 1985-1994 will be somewhat suspect because of the discontinuity in these data occurring in 1992, when NSF survey methodology changed.

As mentioned above, much of this paper's data is taken from the US government's only broad-based survey (23,400 firms surveyed annually) of industrial research and development spending (NSF 1996a). This data set is being used because it has the broadest longitudinal coverage of energy R&D performing private firms. This data set will be used despite acknowledged shortcomings. Two such shortcomings are:

- Neither the survey instrument used to collect this data nor the NSF publication that reports the data make reference to any predefined taxonomy of what are considered to be illustrative examples of energy technologies, and only the most cursory of definitions is given in the survey instrument as to what is meant by the term "energy R&D." Therefore, there is no way of knowing -- by looking at this data set only -- what kinds of energy technologies are being developed by industry.
- The basic unit of analysis for this NSF data set is the "company or enterprise" level, i.e., data are reported at the level of aggregation that will allow for the inclusion of all "establishments under common ownership or control." This means that multi-establishment firms whose business units perform R&D in a wide variety of energy-related areas will have all of its R&D expenditures aggregated into one "energy R&D" figure which will be assigned to whichever business area (i.e., Standard Industrial Classification code) is the largest in terms of total payroll. This will result in overcounting of R&D in the reported, dominant area as well as underreporting of R&D expenditures in the other subsidiary areas.

The most important and apparently intractable of these shortcomings derives from a major revision of the survey methodology used by the government to collect private-sector R&D data in 1992. Two major revisions occurred that year. First, the number of firms surveyed by the government was increased from 14,000 to nearly 23,400. Second, the government discontinued its practice of using partial survey samples in certain years. That is, prior to the 1992, published statistics were based on full samples (i.e., all of the 14,000) carried out at irregular intervals (i.e., 1967, 1971, 1976, 1981, 1987) with data for the intervening years being imputed from a subset (only a few thousand firms) of the last sample (called a panel). For example, the most recent sample prior to the 1992 survey was for survey year 1987. Original estimates for 1988 through 1991 were based on surveys of approximately 1,700 panel companies that reported R&D activity in the 1987 survey. However, beginning with the 1992 survey, statistics are based on full samples (i.e., all of the 23,400 firms) selected annually.

The impact of these revisions can be measured by comparing published data for private-sector energy R&D in 1992 that are printed in the 1992 version of this report (pre-revision) and the same data series that is printed in the 1993 version of this report (post-revision). The 1992 report states that industrial energy R&D funding in 1992 was \$2,812 million, while the 1993 report shows a figure of \$2,084 million for private-sector energy R&D in 1992. That is, the revision to this survey methodology resulted in a \$728 million (26%) downward estimate of private sector energy R&D funding for this year.

Another result of the revisions is that they essentially create two separate data sets: one for 1984-1991 and a second data set for 1992-1994 (NSF 1996b). The National Science Foundation, which is responsible for the publication of these statistics, says that there is no way to correct the pre-1992 data and therefore discourages analysts from performing longitudinal analysis across the time period 1985-1994 like that being performed in this report.

It is difficult — if not impossible — to derive from these statistics insight into the development of specific classes of technologies by US industry.

All private-sector energy R&D data collected by the US government are reported at a very high level of aggregation. This is done because of government rules that prohibit the disclosure of data that could reveal the R&D spending of a particular firm.

Accounts of US public sector energy R&D data in this report differ from standard published accounts of energy R&D contained in the federal budget.

This report's analysis of federal funding for energy R&D is derived from official accounts of budget authority in the Energy R&D (270) Budget Function (NSF July 1996). However, it should be noted that certain "energy R&D" items normally contained in the Energy R&D (270) Budget Function have been dropped from this analysis since they

were judged to not be comparable to private-sector energy R&D investments. Items in the 270 budget function that were dropped for the purposes of this analysis include R&D related to Biological and Environmental Research, "supporting research," Environmental Restoration and Waste Management, university and science education, occupational and public health, Environment Safety and Health, Advanced Neutron Source, and multiprogram lab support.

Appendix #2: Additional Data

Total US Private Sector Energy R&D 1985-1994, in millions of nominal (non-inflation adjusted) US Dollars

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fossil Fuels	\$ 2,024.15	\$ 1,748.29	\$ 1,894.62	\$ 1,863.34	\$ 1,815.67	\$ 2,033.26	\$ 2,238.72	\$ 1,769.59	\$ 1,339.52	\$ 1,310.81
Nuclear	\$ 214.67	\$ 142.43	\$ 159.91	\$ 193.00	\$ 115.67	\$ 156.95	\$ 148.17	\$ 191.18	\$ 183.92	\$ 167.59
Renewable, Conservation, Utilization	\$ 313.00	\$ 281.71	\$ 313.30	\$ 314.00	\$ 416.00	\$ 278.00	\$ 478.00	\$ 474.00	\$ 307.00	\$ 282.00
All other energy R&D	\$ 454.11	\$ 436.03	\$ 485.51	\$ 499.58	\$ 610.65	\$ 658.82	\$ 472.14	\$ 358.70	\$ 572.88	\$ 586.48
Total	\$ 3,005.93	\$ 2,608.45	\$ 2,853.33	\$ 2,869.92	\$ 2,957.98	\$ 3,127.02	\$ 3,337.03	\$ 2,793.47	\$ 2,403.32	\$ 2,346.88

Sources: NSF 1996a; EPRI 1996; GRI 1996.

Modifications: The following modifications were made: GRI's energy R&D was assigned to this report's category of "fossil energy R&D." For 1985-1987, EPRI annual funding for coal R&D is the sum of funding in its Advanced Power Systems and its Coal Combustion Divisions minus \$10 million for renewable R&D. For 1987-1996, EPRI annual funding for coal R&D is the funding for its Generation Division/Group, again minus \$10 million for renewable R&D. (Jim Burke, EPRI's former director of renewable energy research, estimates that research in this category was funded at approximately \$10 million annually for 1985-1996.) The EPRI annual funding for coal was then assigned to this report's category of "fossil energy R&D." EPRI provided data for its nuclear R&D funding for 1985, 1986, and 1993-1996 only; EPRI funding for nuclear R&D for 1987-1992 was estimated by extrapolating from the data provided. This EPRI nuclear R&D funding was assigned to this report's category of "nuclear energy R&D." The remaining EPRI R&D was assigned to this report's "all other energy R&D" category.

Energy R&D Funding at GRI and EPRI 1985-1996

Source: GRI 1996, EPRI 1996.

Energy R&D in the Major (Top 25) US Energy Producers **Millions of constant 1987 US Dollars**

Source: EIA 1996.

Note: The top 25 US energy producers are: Amerada Hess Corporation, Amoco Corporation, Anadarko Petroleum Inc., Ashland Oil Inc., Atlantic Richfield Company, BP America Inc., Burlington Resources INC., Chevron Corporation, Coastal Corporation, E.I. du Pont de Nemours Company, Enron Corporation, Exxon Corporation, Fina Inc., Kerr-McGee Corporation, Mobil Corporation, Occidental Petroleum Corporation, Oryx Energy Corporation, Phillips Petroleum Company, Shell Oil Company, Sun Company, Texaco Inc., Union Pacific Corporation, Unocal Corporation, USX Corporation.

Federal Support for Energy R&D 1985-1994

Source: NSF 1996a.

* Refers to the following modifications to data in the "other energy" (and therefore "total") categories; this reports analysis of federal funding for energy R&D is derived from official accounts of budget authority in the Energy R&D (270) Budget Function. However, certain "energy R&D" items normally contained in the Energy R&D (270) Budget Function have been dropped from this analysis since they were judged to not be comparable to private-sector energy R&D investments. Items in the 270 budget function that were dropped for the purposes of this analysis include R&D related to Biological and Environmental Research, "supporting research", Environmental Restoration and Waste Management, university and science education, occupational and public health, Environment Safety and Health, Advanced Neutron Source, and multiprogram lab support.

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