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IRM Topical Report

An International Comparison of Government Expenditures for Energy Conservation Research and Development

S. C. McDonald

March 1988

Prepared for
the U.S. Department of Energy
Conservation and Renewable Energy
Office of Energy Utilization Research
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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ABSTRACT

This study provides a comparison of U.S. and foreign government spending for energy conservation research and development (R&D). The countries included in this analysis are: the United States, United Kingdom, France, Sweden, West Germany, and Japan. The approach of this paper was to compare the research program of each country at a high level of aggregation with the U.S. Department of Energy (DOE) program structure. This paper does not allow for differences in the way each country defines or accounts for research.

The source data for this study include that collected by the International Energy Agency (IEA). Another good source for international data on research is the Commission for the European Communities (CEC). Previous comparative studies of energy conservation R&D and data supplied by individual countries were also used.

Using the IEA data source, the United States exceeds all other countries in energy conservation R&D expenditures in terms of absolute dollar expenditures. Sweden is first, however, when measuring energy conservation R&D expenditures as a percentage of total energy R&D. Japan is last in energy conservation R&D expenditures using either measure.

High and low estimates of government expenditures were obtained for all countries except France. The difference between these high and low estimates for each country varies from near zero percent to several hundred percent in some cases. It was not possible to assign any degree of confidence to either of these estimates.

Absolute expenditures can be normalized to allow for differences in the sizes of the countries being studied. Three scaling factors were used: 1984 Total Primary Energy Requirements (TPER); 1985 Gross Domestic Product (GDP) and, total central government expenditures. Normalizing by these macroeconomic factors changes the results of the study using both the high and low estimates of expenditures.

Sweden is nearly always first, using either the high or low estimate for expenditures when normalizing the data. Japan is last, or near last using the high estimate. The United States is consistently near the bottom when using

the high estimate, but near the middle when using the low estimate. However, the variation in the relative position of the United States is explained by the great difference between the high and low estimates for other countries, and not for the United States.

Expenditures are only a measure of the inputs to R&D. Expenditures do not measure the benefits or the quality of research, or the efficiency with which research is conducted. Quantifying these R&D outputs, however, is a difficult task. In the meantime, comparisons of government expenditures do provide some measure of the relative importance of a research program. In the case of energy conservation R&D expenditures examined here, however, comparison based on a single source of data such as the IEA may be inadequate given the wide-ranging estimates uncovered.

SUMMARY

This study was completed for the Office of Energy Utilization Research (EUR) in the U.S. Department of Energy (DOE). EUR supports the objectives of DOE in general and the DOE Office of Conservation in particular through research and development (R&D) in generic areas that underpin energy end-use sector technologies. More specifically, EUR has lead responsibility within the Office of Conservation for monitoring and evaluating the current status and future direction of energy conservation-related research in foreign countries.

This study is one of an ongoing series of topical reports related to international energy conservation research and development. Topics are selected based on their overall importance to DOE conservation efforts. This particular paper is a comparative analysis of government expenditures for energy conservation R&D. Knowledge about what other nations are spending for energy conservation R&D has become a priority because of rapid advances in foreign conservation technologies.

PURPOSE AND SCOPE OF THIS STUDY

The purpose of this study is to provide a comparison of U.S. and foreign government spending for energy conservation R&D. The basis for this comparison is the DOE conservation research program. Therefore, the DOE program organization is used as the template for developing a consistent definition of energy conservation R&D.

The countries selected for this analysis are: the United States, United Kingdom, France, Sweden, West Germany, and Japan. Although private research expenditures probably exceed government efforts in most of these countries, private efforts are outside the scope of this study. The time frame for this analysis is the calendar year 1985 or government fiscal years that encompass most of that year.

The approach for this paper was to examine the energy conservation research program of each country at a high level of aggregation. Using the DOE program structure as a model, research programs in other countries were deleted or merged to be consistent with the U.S. definition. Very little program detail was available for some data sources, which made it necessary to accept

that source's definition of energy conservation while noting those differences in the data for which information was available.

This paper is not a bottom-up analysis of energy research in each of these countries. There are certainly differences in the way each country expenses salaries of researchers, equipment costs, and facility overhead charges. A definitive comparison of research expenditures would include an examination and allowance for these differences. However, this study was focused only on aggregate expenditures.

This paper does discuss some of the difficulties and limitations in making comparisons of this sort. These difficulties mostly center on definitional problems or other structural incompatibilities in the data. In addition, there is a discussion of problems associated with international comparisons of financial data, especially when currency conversions are required.

DATA SOURCES IDENTIFIED

The first requirement for a study of this sort is to ferret out and evaluate all potential sources of data. The primary source of data for government expenditures for energy R&D is the International Energy Agency (IEA). The IEA data source includes R&D expenditures for energy conservation R&D for all but one (France) of the countries included in this study.

Another important international data source for R&D information is the Commission for the European Communities (CEC). However, only a subset of the countries included in this study (France, West Germany, and the United Kingdom) are members of the CEC. Other sources of data included in this analysis are previous comparative studies and domestic data sources provided by the subject countries themselves.

IEA ESTIMATES OF GOVERNMENT ENERGY R&D EXPENDITURES

The IEA represents a single source of data for nearly all the countries included in this study. Table 1 presents government expenditures for energy conservation R&D and total energy R&D as originally reported by the IEA. The

TABLE 1. 1985 Government Expenditures for Energy R&D (Millions of 1985 U.S. Dollars)

Country	Energy Conservation R&D	Total Energy R&D	Conservation R&D as Percent of Total
United States	173.6	2,256.3	7.7
United Kingdom	37.1	364.1	10.2
Sweden	22.3	82.3	27.1
West Germany	14.2	548.5	2.6
Japan	12.3	1,557.9	0.8

Source: IEA, 1986, Energy Policies and Programmes of IEA Countries, 1985 Review.

data were converted from domestic currencies to U.S. dollars by IEA using 1985 Organization for Economic Cooperation and Development (OECD) exchange rates.

In terms of absolute dollar expenditures, the United States exceeds all other countries in both total energy and energy conservation R&D. This result is expected since the United States is the largest of these countries in terms of Gross Domestic Product (GDP). However Japan (the second largest economy) ranks last in expenditures for energy conservation R&D while second in total energy R&D.

Table 1 also shows energy conservation R&D expenditures as a percentage of total energy R&D. This measure should give an indication of the degree of commitment within the energy R&D program to energy conservation R&D. The figures in this column range from 27.1% in Sweden to a low of 0.8% in Japan.

From this table it could be inferred that the Japanese do not place a great deal of emphasis on energy conservation research compared with the other countries. This seems surprising, however, given the national priority in Japan towards decreased dependence on petroleum imports (which includes a strong emphasis on conservation). It is possible that the IEA data are not consistent in the measurement of energy conservation R&D across these countries. Through development of alternative estimates of energy conservation R&D expenditures this hypothesis can be tested.

Another possibility is that gross expenditures alone are not a good basis for comparison. Alternative methods of comparison of the data may yield different results. Both of these issues are discussed in the next two sections.

ALTERNATIVE ESTIMATES OF EXPENDITURES

Several other data sources were evaluated for inclusion in this study. In addition to the CEC source noted above, a domestic data source was identified for each country except the United Kingdom. Estimates of energy conservation R&D were derived from these data by first developing a consistent definition for energy conservation R&D and then converting to common U.S. dollars using appropriate exchange rates (Chapter 4). Alternative methods of currency conversion were addressed in light of recent wide variations in exchange rates.

By drawing upon all sources of data including the IEA (Table 1) it was possible to develop a range of estimates for all countries except France. "High" and "low" estimates of government expenditures for energy conservation R&D are presented in Table 2. Unfortunately, it is not possible to formally assign any degree of confidence to either of these extremes, given the limited scope of this study. In some cases a third estimate was also available that was within this range (see Appendix).

TABLE 2. 1985 Government Expenditures for Energy Conservation R&D (Millions of 1985 U.S. Dollars)

Country	High Estimate	Low Estimate	Percent Change Between High and Low Estimate
United States	173.6*	173.5	0.06
United Kingdom	37.1*	11.9**	311.76
France	27.3	27.3	0.00***
Sweden	24.2	22.3*	8.52
West Germany	69.8**	14.2*	491.55
Japan	43.0	12.3*	349.59

Sources: IEA (*), CEC (**), and domestic data sources (see Appendix), (***) only one data source was available.

The difference between the high and low estimates for each country varies from less than one percent for the United States to several hundred percent for West Germany, the United Kingdom, and Japan. The reason for these differences is the complexity in measuring R&D expenditures in general, and in defining those activities which are energy conservation R&D in particular. Moreover, individual countries differ substantially in their R&D record keeping, accounting, and reporting practices.

Energy conservation R&D is not like bicycles or bushels of corn for which there are clear definitions and consistent units of comparison. On the contrary, providing a concise international definition for energy conservation R&D, and a standard format for inclusion and exclusion of expenditure data is a highly complex task (OECD, Frascati Manual). Figures more definitive than those in Table 2 would require substantial and detailed investigation of the energy R&D programs of each country (e.g., Howard).

As can be seen from Table 2, when using the "high" estimate, the United States ranks first in total gross expenditures followed by the West Germany, Japan, the United Kingdom, France, and Sweden. When looking at the "low" estimate, the United States is again first, but France now ranks second. France is followed by Sweden, West Germany, Japan and finally the United Kingdom, when using the low estimate.

NORMALIZED COMPARISONS OF EXPENDITURE DATA

Absolute R&D expenditures can be misleading because of the relative sizes of the economies being studied. Normalization of the expenditure data can be accomplished using scaling factors to adjust for these differences. Table 3 contains selected macroeconomic data for normalization of expenditures for each of the countries.

Column one of Table 3 shows the 1984 Total Primary Energy Requirements (TPER) of each country expressed in millions of tons of oil equivalent (MTOE). Column two contains the 1985 Gross Domestic Product (GDP) or Gross National Product (GNP). Finally column three lists total expenditures of the central government in 1985 for each of these nations.

TABLE 3. Economic Data for Normalization of Expenditures

Countries	1984(a) TPER (MTOE)	(Billions of of 1985 U.S. Dollars) 1985 GDP	1985 Expenditures
United States	1800.1	397.7	946.3
United Kingdom	191.8	452.2	183.4
France	191.3	511.4	110.6
Sweden	49.3	99.9	46.5
West Germany	263.5	621.7	87.3
Japan	377.2	1,325.2	220.1

(a) Most recent year available.
Source: OECD, Energy Balances of OECD Countries, 1983/1984, IMF, International Financial Statistics Yearbook, 1986, U.S. OMB and embassy finance offices.

As can be seen in Table 4, normalizing expenditures by these macroeconomic data reveals a different story than just the simple comparison of gross expenditures. Using the high estimate from Table 2, Sweden (0.49) ranks first and West Germany (0.26) second in expenditures per TOE. Interestingly, Sweden's ratio is nearly twice that of the nearest country, West Germany. The United States is last behind Japan using this same measure.

TABLE 4. Energy Conservation R&D Expenditures Per Total Primary Energy Requirement (Dollars per Ton of Oil Equivalent)

Country	High Estimate	High Rank	Low Estimate	Low Rank
Sweden	0.49	1	0.45	1
West Germany	0.26	2	0.05	5
United Kingdom	0.19	3	0.06	4
France	30.14	4	0.14	2
Japan	0.11	5	0.03	6
United States	0.10	6	0.10	3

Source: Tables 2 and 3.

When the low estimate is employed, the rank order changes somewhat. Sweden is once again first but is now followed by France in expenditures per TOE of TPER. The United States falls clearly into the middle of the ranking with the United Kingdom, West Germany, and Japan following in descending order.

Table 5 shows energy conservation R&D expenditures as a percentage of GDP. From this table it can be seen that when using the high estimate, Sweden (0.024%) is once again first, spending the most for conservation research as a percentage of GDP. The United States (.004%) is next to last, just slightly ahead of Japan (0.003%).

Finally, Table 6 shows government expenditures for energy conservation R&D as a percentage of total government expenditures (budget). West Germany

TABLE 5. Energy Conservation R&D Expenditures as a Percentage of Gross Domestic Product (GDP) (%)

	High		Low	
Country	Estimate	Rank	Estimate	Rank
Sweden	0.024	1	0.022	1
West Germany	0.011	2	0.002	5
United Kingdom	0.008	3	0.003	4
France	0.005	4	0.005	2
United States	0.004	5	0.004	3
Japan	0.003	6	0.001	6

Source: Tables 2 and 3.

is first among these nations (high estimate) in terms of research expenditures as a percentage of total government budget. West Germany is followed by Sweden, France, the United Kingdom, Japan, and finally the United States. Using the low estimate, Sweden is once again preeminent, with Japan and the United Kingdom both in last place.

TABLE 6. Energy Conservation R&D Expenditures as a Percentage of Total Government Expenditures (%)

Country	High		Low	
	Estimate	Rank	Estimate	Rank
West Germany	0.080	1	0.016	4
Sweden	0.052	2	0.048	1
France	0.025	3	0.025	2
United Kingdom	0.020	4	0.006	5
Japan	0.020	4	0.006	5
United States	0.018	5	0.018	3

Source: Tables 2 and 3.

LIMITATIONS OF COMPARATIVE EXPENDITURES ANALYSIS

There are significant difficulties in trying to base policy decisions solely on comparisons of expenditure figures. For instance, questions regarding whether U.S. spending is sufficient when compared to other nations are not well addressed using expenditure data alone. In light of this study, a definitive statement as to how much the United States spends for energy conservation R&D in comparison with other major OECD countries cannot be made.

Energy conservation R&D expenditures are only inputs to the R&D effort. Dollars spent for energy conservation R&D, in and of themselves, do not measure the benefits of this research or the efficiency with which that research is conducted. Moreover funding levels do not address the quality of research performed in a given country, differences in relative costs of research, or the area of technical emphasis within the R&D program.

A more complete study would include several measurements of research including costs and benefits of research, plus some measure of the efficiency of the research effort. Unfortunately, it may be even more difficult to quantify these R&D outputs. For now though, comparative studies of government expenditures in energy R&D programs based solely on IEA data should be given close scrutiny given the wide variations in estimates of expenditures derived in this study.

FINDINGS

Aside from differences in reporting by individual countries, the IEA data seem to be internally consistent in that they measure the same phenomena within a country from year to year. Often there were wide variations between IEA data and data from other sources. Given these discrepancies, it may be that IEA data are not as reliable for detailed comparisons among countries.

Data from individual countries lack the comparability among countries expected from a unified database like that of the IEA or CEC. An attempt was made to make these domestic data sources consistent using the U.S. energy conservation research program structure as a template. However, adjustments to the data did not allow for other differences in the way countries manage, expense, and report research programs.

Problems of data definition and transformation pose important limits to a comparison of this sort. However, using multiple data sources, this work provides some evidence that public spending for energy conservation R&D may be less a priority for the United States than, say, Sweden and France. Given the wide range of expenditure results, it is not possible to draw firm conclusions regarding the importance of energy conservation R&D in the United Kingdom, West Germany, or Japan. From the evidence provided, it seems that expenditure data can be used to crudely evaluate the relative importance of a particular research area within a country, but not the quality of the research activities or results.

FREQUENTLY USED ACRONYMS

AFME	l'Agence Francaise pour Maitrise de l'Energie (French Energy Management Agency)
BMFT	Bundesministerium fur Forschung und Technologie (Ministry for Research and Technology, FRG)
CEC	Commission for the European Communities (See EC)
CR	Congressional Record
CY	Calendar Year
DfE	Energy Research and Development Commission (Sweden)
DH	District Heating
DM	Deutsche Marks (German Currency)
DOE	Department of Energy
DoE	Department of Energy (United Kingdom)
EC	European Community
EUR	Energy Utilization Research
FF	French Francs (French Currency)
FRG	Federal Republic of Germany (West Germany)
FY	Fiscal Year
GDP	Gross Domestic Product
GNP	Gross National Product
IEA	International Energy Agency
IMF	International Monetary Fund
MTOE	Millions of tons of oil equivalent
NABS	Nomenclature for the Analysis and comparison of Science programs and Budgets (EC Terminology)
NSF	National Science Foundation
OECD	Organization for Economic Cooperation and Development

FREQUENTLY USED ACRONYMS (contd)

OMB	Office of Management and Budget (United States)
PPP	Purchasing Power Parities
£	Pounds Sterling (United Kingdom Currency)
R&D	Research and Development
RD&D	Research, Development and Demonstration
SEK	Swedish Kronor (Swedish Currency)
TPER	Total Primary Energy Requirements
UK	United Kingdom
US	United States
¥	Yen (Japanese Currency)
$	Dollars (United States Currency)

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FIGURE

TABLES

1.0 INTRODUCTION

1.1 PURPOSE

This paper provides an international comparison of published central government expenditures for energy conservation research and development (R&D). Another purpose of this study is to describe the problems in deriving comparable expenditure data and discuss the limitations to analysis posed by the data. The countries chosen for this study are: the United States, United Kingdom, France, Sweden, West Germany, and Japan.

1.2 BACKGROUND

It is important to gain a sense of what other countries are doing in areas of R&D. By studying foreign government energy conservation R&D efforts, U.S. researchers gain a sense of which technical areas are important and how this research is conducted. Government R&D expenditure data can provide useful insight into these issues, particularly in a comparative analysis.

Government-directed and -supported R&D fulfills two basic purposes. First, government spending frees private dollars for research more commercial in nature. Also, government can conduct research that is too high-risk for a single firm, either due to the high cost or the perceived inability to protect the research results.

Second, government can help focus R&D efforts by selectively supporting certain areas of research. By identifying and funding basic research in promising technologies, governments can help support future economic growth and foster national security. An example of this would be biotechnology, which several governments have chosen to support as a potential future growth area.

Both of these functions relate to the international competitiveness of industry. By supporting R&D, governments reduce costs for industry, and make them more competitive in the international arena. If the research is successful, companies can develop new or higher-quality goods, or more efficient

processes and thereby gain a competitive advantage. Finally, government-supported research can promote economic development by providing the technical base for launching new high-tech industries or by helping achieve significant technical breakthroughs in existing industries.

Energy conservation R&D has an impact in several of the areas outlined above. The most readily identifiable benefit would be cost savings to industry realized through more efficient use of energy. Some of the most energy-intensive industries (e.g., primary metals and bulk chemicals) are also those that have suffered greatest from the influx of relatively cheaper foreign imports.

1.3 SCOPE AND ORGANIZATION OF THIS REPORT

This paper is an international comparison of central (federal) government expenditures for energy conservation R&D. Private R&D efforts in energy conservation may dwarf public expenditures in some countries (NSF, 1985), but are not included in this report. The most recent year for which comparable government expenditure data is available is 1985, which is the time frame for this analysis. This paper presents the various sources of the data, discusses problems associated with international data comparisons, and, finally, provides a series of comparisons of government expenditures.

This paper uses the DOE program of energy conservation research as the basis for comparison. The major research program elements are shown below:

1. Buildings and Community Systems - includes residential and commercial buildings
2. Industrial Technologies
3. Transportation Systems
4. Multisector - includes generic R&D in combustion, tribology, materials, and biotechnology.

Key energy savings programs that are excluded by this definition are: all coal-based R&D, fuel cells, energy storage, and electrical transmission and distribution. Major research program elements within each country are

examined to determine consistency with this definition. This study does not allow for differences among countries in cost accounting or reporting practices for research projects.

The paper contains five sections. Section 2 presents the conclusions drawn from this analysis. Section 3 presents the IEA data source and forms comparisons based upon those data. Section 4 presents the methodology used to construct a comparable set of data and the sources of those data. Finally Section 5 compares high and low estimates of energy conservation R&D expenditures based on the data presented in Sections 3 and 4.

2.0 CONCLUSIONS

This section contains conclusions drawn from the evidence presented in Sections 3, 4, and 5. There is a brief discussion of the data sources and R&D expenditure comparisons. This section also draws from a discussion in Section 4 on the problems associated with comparisons of international financial data. The results of comparisons made in Sections 3 and 5 are presented. Finally, some recommendations are made for future studies in this area.

2.1 EXPENDITURE DATA FOR ENERGY CONSERVATION R&D

The IEA continues to be the primary source of data for government expenditures for energy conservation R&D. However, there is a good deal of discrepancy between IEA-reported data and data available from other international data sources (e.g. the CEC) and the individual countries themselves. These differences in reported values are due primarily to differences in data definition, data reporting, and data collection methodologies among the data sources.

The IEA data do seem to be internally consistent for a particular country from one year to the next (i.e., it is measuring the same phenomena within a country over time). There are strong indications, however, that the IEA data are not as reliable for comparison among countries when considering variations from the other data sources. Therefore, comparisons among countries based solely on IEA data may not paint a true picture of existing conditions.

Data from individual countries lack the comparability among countries that would be expected from a unified database like that of the IEA or CEC. An attempt was made to make these domestic data sources consistent through comparisons with the U.S. program for energy conservation research. This adjustment does not allow for other differences in domestic cost accounting and reporting practices.

2.2 DATA CONVERSION

There are difficulties associated with international comparisons of expenditure data in addition to those noted above. Volatile exchange rates

greatly impact conversion of data from national currencies to a common currency for purposes of comparison. An alternative to exchange rates is the use of Purchasing Power Parities (PPPs).

PPPs are designed to fluctuate to reflect the relative difference in inflation rates between two nations (Kravis). Use of PPPs is growing, having been adopted by both the World Bank and International Monetary Fund (IMF) among other international organizations. Unfortunately, currency conversion was limited to the exchange rate method in this paper to maintain comparability with the IEA data source which uses this methodology for currency conversions.

2.3 INTERNATIONAL COMPARISON FINDINGS

High and low estimates of government expenditures for energy conservation R&D were produced in this study. These two estimates represent the extremes in expenditure figures as derived from the various data sources. These estimates vary by over two thousand percent in some cases (Japan). However, it was not possible to assign a degree of confidence to either extreme.

Gross (absolute) government expenditures in and of themselves are of limited use for comparison due to the relative size of the economies being studied. To allow for these differences, scaling factors were developed for the data. These scaling factors include TPER, GDP, and total budget of the central governments.

The countries were ranked according to their energy conservation R&D expenditures per unit of scaling factor. The rank order of the countries changed depending on the estimate (high or low) of expenditures being used and the scaling factor used to weight these estimates. However, Sweden is consistently first or second in the high estimate while the United States ranks last. Japan is near the bottom using the low estimate, while Sweden is consistently first, with the United States third.

Wide variations between high and low estimates for some countries make it difficult to draw firm conclusions about the relative importance of energy conservation R&D in these countries. Still, based on the available data, it appears that energy conservation R&D is a more important priority for Sweden

and France than for the United States. The relative importance of energy conservation R&D is less certain for Japan, West Germany, and the United Kingdom.

2.4 NOTES AND RECOMMENDATIONS

Problems of incompatible data definition and data transformation pose severe limits to an international comparison of this sort. A more complete identification of the energy R&D program in each country would further highlight the differences in organization and content of these programs. This would aid in identifying those research activities that are truly energy conservation related.

A solution is also needed to the problem of converting the financial data to common units for comparison. This could be accomplished by using PPPs or by limiting the analysis to comparisons that do not require currency conversions (e.g., proportion to total R&D budget or government expenditures).

The simple adjustment of domestic data through comparison with the U.S. program slate was the approach used for this study. It assumes, however, that the definition of energy conservation research differs solely by the organizational structure of the research program. A more rigorous approach would include a careful and time consuming examination of the scope of each research program for consistency with the adopted definition. More consideration should also be given to the manner in which research costs are expensed to individual projects (e.g., facility charges, equipment depreciation, and salaries of researchers).

Despite these limitations, this is useful work in trying to establish a basis for comparison of expenditure figures for energy conservation R&D. At a minimum, the results of this study show the potential pitfall of comparative analyses of energy research expenditures based solely on the IEA data source. In addition, this study has defined a number of problems that will need to be resolved to derive more meaningful comparisons of energy conservation research expenditures.

3.0 COMPARISONS USING IEA DATA

This section is devoted to a comparison of government expenditures for energy conservation R&D based solely on the IEA data source. A description of the IEA data and data collection methodology is provided. Various methods of data comparison appear in later sections.

3.1 IEA EXPENDITURE DATA

The IEA is a an autonomous organization under the auspices of the OECD. Among other functions, the IEA collects and publishes data for energy R&D expenditures by member countries (IEA 1985; IEA 1986). All of the countries covered in this report, except France, are members of the IEA.

The IEA also organizes joint research for member countries. These research activities are conducted on either a cost-shared or task(work)-shared basis. The IEA data for government expenditures for energy conservation R&D include contributions to these IEA R&D activities.

The collection and reporting of energy research activities by the IEA closely resemble the U.S. program. These similarities facilitate comparisons between the United States and countries with similar organizational structures (e.g. Sweden). However, comparisons with countries not so inclined are more difficult, most notably Japan.

Another important feature of the IEA data is that it purposefully excludes basic research unless this research is directly energy-related (IEA/CRD). This requires a judgement call by the questionnaire respondents and may result in inconsistent reporting of the data. The data may also be biased for countries that stress basic research in the overall program.

Table 3.1 compares the U.S. energy conservation program with the method of data classification employed by the IEA. IEA data for energy conservation R&D expenditures are subdivided into Industrial; Residential and Commercial; Transportation; and, Other (IEA/CRD). These major groupings are similar to those used by DOE, however, assignment of research activities within these technology areas is different.

TABLE 3.1. Comparison of IEA and U.S. Department of Energy (DOE) Energy Conservation R&D Program Definitions

DOE	IEA
Building and Community Systems	**Residential and Commercial**
Building systems	Space heating and cooling
Residential conservation service	Ventilation and lighting control systems
Community systems	Low-energy housing design and performance
Urban waste	New insulating materials, thermal performance of buildings
Technology and consumer products	Domestic appliances
Appliance standards	
Analysis and technology transfer	
Federal Energy Management Program	
Industrial	**Industry**
Waste energy reduction	Reduction of energy consumption in industrial processes including combustion
Industrial process efficiency	Development of new techniques, new processes and new equipment in metallurgical, petrochemical, chemical, glass, paper and pulp, textile, food industries
Industrial cogeneration	
Implementation and deployment	
Transportation	**Transportation**
Vehicle propulsion R&D	Analysis and optimization of energy consumption in transportation sector
Electric and hybrid vehicle R&D	Public transportation systems
Transportation systems utilization	Engine-fuel optimization
Alternative fuels utilization	Use of alternative fuels fuel additives
Advanced materials development	Diesel engines, stirling motors, electric cars, hybrid cars
High-temperature materials laboratory	
Multisector	**Others**
National appropriate technology and assistance service	Waste heat utilization
Energy related inventions program	District heating
Energy conversion and utilization technologies (combustion, thermal sciences, materials, catalysis/biocatalysis, tribology)	Heat pump development
	Recycle and use of urban and industrial wastes
	Use of wastes and low-temperature heat in agriculture

Source: NSF, Federal R&D Funding by Budget Function: Fiscal Years 1985-87, and IEA, Questionnaire for Country Submissions for the 1986 Review of National Energy Policies and Programmes, OECD, March 27, 1986.

Interesting points for comparison are Stirling motor research and Waste Heat Utilization and District Heating. Under the IEA classification scheme, Stirling motor research would be categorized under Transportation while Waste Heat Utilization and District Heating is lumped with "Other." In the U.S. program, both Stirling motor and Waste Heat Utilization and District Heating are in the Buildings and Community Systems classification. Therefore, it may be difficult to compare energy conservation R&D expenditures at this disaggregated level.

3.2 COMPARISONS OF GROSS EXPENDITURES

The IEA data for total energy conservation R&D and total energy R&D are contained in Table 3.2. Since France is not a member of the IEA, figures are only available for the United States, United Kingdom, West Germany, Sweden, and Japan. Expenditure data for energy conservation R&D are only published in U.S. dollars. The data were converted by the IEA from domestic currencies into millions of 1985 U.S. dollars using average 1985 exchange rates. More recent data would reflect the significant devaluation of the U.S. dollar relative to the currencies of these other countries.

TABLE 3.2. 1985 Government Expenditures for Energy R&D (Millions of 1985 U.S. Dollars)

Country	(1) Energy Conservation R&D	(2) Total Energy R&D	(3) % (1)/(2)
United States	173.6	2,256.3	7.7
United Kingdom	37.1	364.1	10.2
Sweden	22.3	82.3	27.1
West Germany	14.2	548.5	2.6
Japan	12.3	1,557.9	0.8

Source: IEA, 1986, "Energy Policies and Programmes of IEA Countries, 1985 Review."

According to IEA data, the United States ranks first in absolute dollars spent on energy conservation R&D, followed by the United Kingdom, Sweden, West Germany, and Japan. The order is changed somewhat when considering total energy R&D. In this instance, the United States again ranks first, but Japan is next followed by West Germany, the United Kingdom, and finally Sweden.

Column 3 of Table 3.2 shows energy conservation R&D as a percentage of total energy R&D. Sweden spends the greatest proportion of its total energy R&D budget for energy conservation R&D (27.1%). Next are the United Kingdom (10.2%) and the United States (7.7%), which devote roughly equivalent portions of their energy R&D budgets for energy conservation. Surprisingly, both West Germany and Japan spend only a small fraction of their energy R&D budget for energy conservation, with Japan designating less than 1% to conservation.

3.3 OTHER BASES FOR COMPARISON

Gross expenditures, while containing some interesting information, are of limited use in explaining the degree of commitment by the central governments to energy conservation R&D. Absolute dollars do not address the differences in the relative magnitude of the economies of the countries being studied. To obtain a better estimate of the relative support for energy conservation R&D, it is desirable to weight gross expenditures for energy conservation R&D by a scaling factor that reflects the differences in magnitude of the economies.

Many possible scaling factors or weights can be used to scale the expenditures data. Three such weights, GDP, Energy Requirements, and Population were used in a previous analysis (Ketoff) and produced interesting results. Both GDP and Energy Requirements are used in this paper as well.

A third scaling factor, total central government expenditures, is used in lieu of a per capita measure of energy conservation R&D expenditures. Scaling by total government expenditures is believed to be a better measure of the government commitment to energy conservation R&D. Table 3.3 contains the three scaling factors identified for each of the six countries contained in this study.

TABLE 3.3. Total Primary Energy Requirements, GDP, and Government Budgets

Country	1984 TPER (MTOE)	Billions of 1985 U.S. Dollars	
		1985 GDP	Central Government Budget
United States	1,800.1	3,947.7	946.3
United Kingdom	191.8	452.2	183.4
France	191.3	511.4	110.6
Sweden	49.3	99.9	46.5
West Germany	263.5	621.7	87.3
Japan	377.2	1,325.2	220.1

Source: OECD, Energy Balances of OECD Countries, 1983/1981, IMF, International Financial Statistics Yearbook, 1986, U.S. OMB, and Embassy Finance Offices.

Column one of Table 3.3 contains the 1984 TPER in MTOE. Column two contains the 1985 GDP, while column three contains the budgets of the central governments of the six countries. Both columns two and three are in billions of 1985 U.S. dollars.

Table 3.4 presents energy conservation R&D expenditures normalized using the scaling factors listed in Table 3.3. Each normalized figure is followed

TABLE 3.4. Energy Conservation R&D Expenditures Normalized by Various Measures

Country	Dollar/ TOE	Rank	Percent GDP	Rank	Percent Budget	Rank
Sweden	0.45	1	0.022	1	0.022	1
United Kingdom	0.19	2	0.008	2	0.020	2
United States	0.10	3	0.004	3	0.018	3
West Germany	0.05	4	0.002	4	0.016	4
Japan	0.03	5	0.001	5	0.006	5

Source: Tables 3.2 and 3.3.

by the relative ranking of energy conservation research expenditures. Column one shows research expenditures weighted by energy use. Since both the government expenditure data from Table 3.2 and TPER from Table 3.3 are in millions, the units in Table 3.4 are in dollars per TOE.

Column three presents energy conservation R&D expenditures as a percentage of GDP. Likewise, column five shows expenditures as a percentage of the central government budget. Since R&D expenditures are in millions of dollars (see Table 4.3) and both GDP and the government budgets are in billions of dollars (see Table 4.4) the percentages are quite small.

It is interesting to note that the relative ranking of government expenditures is unaffected by any of these normalizing methods. Using these measures, Sweden is always first, the United Kingdom second, followed by the United States, West Germany, and Japan. These relative rankings are of such a magnitude of difference that only a significant change in the percentage difference in energy conservation research expenditures will elicit a change in the rankings.

3.4 CONCLUSIONS BASED ON COMPARISONS USING IEA DATA

Gross expenditures for energy conservation R&D, while important, do not allow for differences in size of the countries. Scaling the IEA data by selected macroeconomic data provides a different measure of government support for conservation research by placing the expenditure data into perspective. However, no additional information was obtained since the rank ordering of the countries was not impacted by the choice of scaling factors.

Sweden is far and away the leader in government-sponsored conservation research, after normalization of the data. The relative spread between Sweden, the leader, and Japan (which is always last) as given by these measures is substantial. If these figures are true, one reason for the relative importance of energy conservation research in Sweden may be the emphasis on buildings research given Sweden's relatively cold climate. In addition, Sweden, which is moving away from nuclear energy, spends very little for nuclear energy research thereby freeing funds for other research areas such as energy conservation. Nuclear research comprises a large portion of the energy research budget of the four other countries (IEA, 1985).

The wide variations in the normalized expenditures for energy conservation research may be a result of inconsistencies in the IEA data. This hypothesis can be tested by developing alternative data sources and making comparisons with the IEA data. This is the goal of the remainder of this study.

4.0 DEVELOPING ALTERNATIVE DATA

This section documents the attempt to develop comparable expenditure data from alternative sources. There were difficulties encountered in adopting a concise definition of energy conservation R&D (Section 4.1). The methodology used to construct the alternative data series is identified in Section 4.2. This section also contains a more detailed discussion of the merits of alternative means of converting financial data to common currencies. Finally, the alternative data sources are presented and discussed although much of the detail for the domestic data is contained in the Appendix.

4.1 DATA DEFINITION

Problems of data definition are twofold in this study. First, there is the issue of what research areas are to be considered as related to energy conservation. For example, in some countries, areas of research impact energy efficiency but are not conducted with energy conservation as the primary goal. Secondly, there is the issue of where research and development ends and where the application of new technologies begins. This latter phase can be described as the demonstration and commercialization of a new product or technology. Both of these issues are described in greater detail in the following subsections.

4.1.1 Energy Conservation

No one internationally accepted definition of energy conservation R&D exists. The direction and emphasis, and hence definition, of energy conservation R&D within a country depends on factors such as geography, economic structure, social attitudes, and government policy choices. These factors tend to become institutionalized, with government programs in energy conservation R&D designed accordingly. Whether R&D efforts are designated as energy conservation, therefore, depends on these institutional structures.

To proceed with a comparison of energy conservation R&D expenditures, it was first necessary to adopt a standard definition. Since the results of this study are intended for use by DOE officials, the research program of the Office of Conservation and Renewable Energy is used as the standard. This programmatic definition is less rigorous than one defined by scientific or

engineering principles. Such a definition would require much more detailed analysis of individual research programs within countries, which is outside the scope or resources of this study.

The U.S. energy conservation R&D effort is carried out under four broad program areas: Buildings and Community Systems, Industrial Programs, Transportation Systems, and Multisector. Buildings and Community Systems research focuses on building design and weatherization as well as energy efficiency in consumer products. The Industrial program carries out research directed towards energy savings in a broad range of industrial processes. Transportation includes energy conservation research efforts in alternative fuels, automotive materials, electric vehicles, and the like. The Multisector program encompasses crosscutting technologies such as combustion, advanced materials, and tribology that are applicable to any or all of the other areas.

It is unlikely that a perfect correspondence will be obtained between this definition and the definitions used by all the sources of data presented in this chapter. Therefore, it was necessary to carefully examine the specific "Energy Conservation R&D" programs that constitute the expenditure data from each of these sources. Through such an examination, a decision can be made whether to include that program (expenditure) in the total for comparison purposes.

4.1.2 Research and Development

Research and Development can be subdivided into a series of overlapping stages. Research can be described as either Basic, Generic Applied, or Applied research (OTA, 1984). Basic research seeks to gain fundamental understanding of phenomena with little concern for specific commercial application. Applied research, on the other hand, is research directed towards a particular product or process with the ultimate goal of marketing a new technology. Generic applied research lies somewhere between these two.

Applied research also tends to be more closely associated with the Development stage of R&D. Development includes construction and testing of prototypes for engineering feasibility. Outside the United States, the term

Research, Development and Demonstration is also used when referring to R&D(&D). Demonstration programs are used to show economic (commercial) feasibility of a product or process.

The role of government in each of these stages varies among countries. The United States, for instance, tends to focus efforts on basic and generic applied research while leaving applied research and development to private industry. West European countries, except West Germany, spend proportionally more of their research budget on applied research and demonstration programs. The same holds true for Japan.

The problem that arises in this study is the issue of when to include certain types of research and demonstration programs in the totals for energy conservation R&D. Accepting each R&D program (expenditures) at face value may be a correct assessment of energy conservation research for that country, however, the programs may not be comparable across countries. Unfortunately some data sources (IEA, CEC) are not disaggregated to the level where such detailed analysis can take place.

An example of this problem is basic research that is not specifically targeted towards "energy conservation" within a country but yields new technologies that do conserve energy. Including all basic research would show the United States and West Germany spending proportionally more on energy conservation R&D than the remaining countries in this study (NSF 86-310). As another example, including demonstration programs would raise expenditures for both the United Kingdom and Japan, which emphasize this stage of R&D(&D). These differences in reporting of Research and Demonstration (and Development) are a major source of variation in some data sources (IEA, CEC) and will be discussed later.

4.1.3 Other Definitional Issues

There is a myriad of other definitional issues with regard to how individual countries collect and report data for energy conservation R&D expenditures (Lederman). For instance, are researcher salaries expensed to energy conservation R&D projects within a country, or are funds for these salaries disbursed from a general account? Are graduate students, a major resource in

university research, compensated or is their effort on a volunteer basis as part of the educational experience? Do expenditure figures include capital expenditures or depreciation?

Some international data sources have attempted to overcome some of these institutional differences in reporting of government R&D expenditure figures (Frascati Manual). These guidelines have resulted in databases that are internally consistent for each country from one year to the next. However, comparisons across countries are still difficult because of unresolved differences in data collection methodologies (Blades). These differences, when uncovered, are discussed further when comparing data from the various sources.

4.2 CONSTRUCTION OF DATA SERIES

Section 3.0 presented gross expenditure data for energy conservation R&D as obtained from the various data sources. This section presents the methodology used to formulate the comparisons in Section 5. Included in this section is a discussion of the differences in fiscal years of the various governments. Two possible methods for conversion of gross expenditure data from national currencies to common currencies, are presented. Finally, there is a discussion of alternative methods of comparison of the data other than gross expenditures.

4.2.1 Time Frame

The data reported by the IEA is for the calendar year 1985. It is not clear, however, that the data has been adjusted from fiscal year (FY) data to calendar year for each of the reporting governments. This appears to be true for the United States, at least, given the close correspondence of energy conservation R&D figures reported by the IEA and those derived in Section 3.2.4.

All data obtained from domestic sources is reported for the government FY. Figure 4.1 is a time line that shows the relationship between the calendar year and the approximate beginning of the FY for each country. For purposes of this study, the data remains as reported for the FY beginning 1985. No attempt is made to adjust overlapping budget years by averaging to the calendar year.

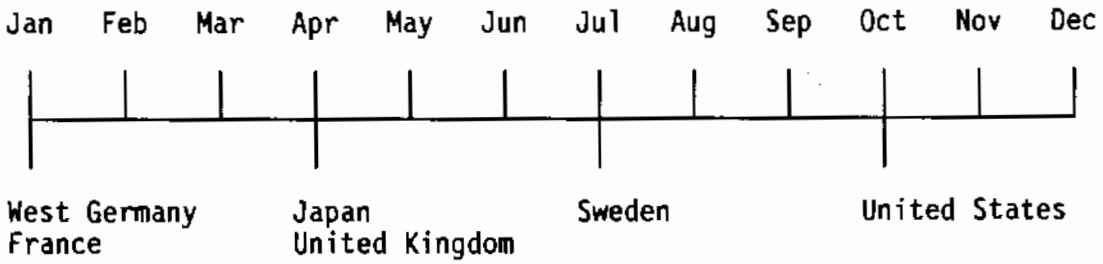

FIGURE 4.1. Time Chart Relating Calendar Year to Fiscal Year of Governments

4.2.2 Data Conversion

Comparisons among countries are difficult because of relative currency valuations across countries and differences in purchasing powers within countries. The U.S. dollar, the most common unit to which data is converted for purposes of comparison, has been subject to wide variations in exchange rates over the past few years. This impacts the absolute magnitude of energy conservation R&D expenditures of each of the countries if these data have been converted to U.S. dollars using exchange rates. In other words, the ranking of the countries by expenditure levels becomes somewhat dependent on the time period chosen and the nominal exchange rate employed.

The IEA methodology for conversion of domestic financial data to U.S. dollars is to use OECD exchange rates. To facilitate comparisons with the IEA data, the same methodology was used when converting data from the alternative sources identified here. However, the use of PPPs was also investigated and warrants a brief discussion.

PPPs, like exchange rates, allow financial data from different countries to be expressed in a common currency for comparison (see Kravis or Dreschler). However, unlike exchange rates, PPPs are a derived measure, and are therefore not subject to short-term speculative pressures and equilibrating forces of the currency markets. PPPs are designed to capture only the relative difference in inflation rates between two nations. Because of this greater stability, there is a growing use of PPPs for conversion of international currency data.

Table 4.1 contains 1985 PPPs used for conversion of GDPs, and exchange rates for the six countries included in this study (OECD 1987). As can be

TABLE 4.1. Comparison of Currency Conversions to 1984 U.S. Dollars

Country	(1) Purchasing Power Parities 1985	(2) Purchasing Power Parities 1986	(3) Percent (1)/(2)	(4) Exchange Rates 1985	(5) Exchange Rates 1986	(6) Percent (3)/(4)
United States	1.00	1.00	100.0	1.00	1.00	100.0
United Kingdom	0.57	0.57	100.0	0.78	0.68	114.7
France	7.33	7.48	98.0	8.98	6.93	129.6
Sweden	8.21	8.50	96.4	8.60	7.12	120.7
West Germany	2.48	2.48	100.0	2.94	2.17	135.5
Japan	225.00	223.0	100.8	239.00	169.00	141.4

Source: OECD, Purchasing Power Parities and International Comparisons of Price Levels and Real Per Capita GDP in OECD Countries, PRESS/A(87)9, February 1987.

seen from this table, there is little change in relative purchasing power among these countries from 1985 to 1986 when using PPPs (Column 3). However, the difference when using exchange rates is dramatic (Column 6).

For instance, the purchasing power of the Japanese yen, appreciated just 0.08% against the U.S. dollar during this period. When using exchange rates, the yen is seen to appreciate over 41.0% from 1985 to 1986. With France and Sweden, PPPs show a relative depreciation in value against the dollar from 1985 to 1986. Conversely, exchange rates show these currencies appreciating during this same two-year period.

This recent instability in exchange rates for the dollar against these foreign currencies directly impacts this analysis. The relative magnitude of all the financial data in a particular year becomes highly dependent on the exchange rate for that year. Though PPPs are more often used when comparing wealth measurements such as GDP, given the recent volatility in exchange rates, they may be justifiably used in future analyses such as this.

4.3 ALTERNATIVE DATA SOURCES

This section reviews each alternative source of data for comparison of government expenditures for energy conservation R&D. Previous comparative

studies are considered first, followed by a review of international and domestic sources of data. Detailed analyses of domestic sources of data are reserved for the Appendix.

4.3.1 Previous Studies

There have been several prior attempts at making comparisons of energy conservation R&D expenditures. Among these was Ketoff (1986) which developed expenditure figures for the United Kingdom, France, West Germany, Japan and the United States. In this study, the author distinguished between energy conservation R&D and energy conservation "programs." Although no strict definition is given for this division, it is stated that at least part of the energy conservation program data for the United States are for the Low Income Housing and Energy Assistance Program. This program is not R&D in nature, and would not be within the scope of this paper.

Ketoff did present separate expenditure figures for energy conservation R&D only. Unfortunately, it is not always easy to match specific figures with information sources. Thus the usefulness of these data is limited for purposes of this study. However, Ketoff did provide a series of useful methods for comparing data, which will be addressed in the next chapter.

A 1981 study, by DHR, Inc., had an expanded list of countries including: Australia, Canada, and the Netherlands. Unlike the Ketoff work, the data sources were well documented in this report. However, most of the data were derived from IEA sources. Since the IEA is used as a primary source of data for this study, and because the DHR figures are now out of date, results of that report will not be used.

4.3.2 Commission for the European Communities

The Commission for the European Communities (CEC) is an international cooperative organization of European nations in areas of economic and social policies. Along with agreements in social and economic areas, the CEC conducts surveys of various activities of member countries, including government expenditures for energy R&D. Three of the countries included in this study are also members of the CEC: France, West Germany, and the United Kingdom.

Table 4.2 presents total energy R&D expenditures and expenditures for energy conservation R&D as defined by the CEC Nomenclature for the Analysis and

comparison of Science programs and Budgets (NABS). A major difference in definition between the IEA and CEC data is that IEA includes demonstration programs while CEC does not. In addition, CEC data include some basic research not included in IEA data because it cannot be directly attributed to energy (or energy conservation).

Table 4.2 contains the most recent available data, which are for 1984. France does not provide disaggregated data for R&D expenditures. Therefore only total energy R&D expenditures are available for France.

The expenditure figures in Table 4.2 represent energy conservation R&D activities in the individual CEC countries. However, the CEC, like the IEA, also conducts joint research projects in energy conservation for member countries. Unlike IEA-managed research, monies for CEC energy R&D are drawn from a general R&D account. Therefore, it is not possible to determine which portion of a member's contribution to general R&D is directly attributable to energy conservation R&D.

It might be possible to develop a weighting scheme to share out energy conservation from total R&D contributions by member countries. However, such a methodology was not used here. Therefore, neither energy conservation R&D (Column 1) nor total energy R&D (Column 2) in Table 4.2 includes contributions by CEC members to community-sponsored R&D in energy conservation. As a result of this exclusion, true expenditures by CEC member countries for energy conservation R&D might be somewhat understated.

TABLE 4.2. 1984 Government Expenditures for Energy R&D (Millions of 1984 National Currencies)

Country	Energy Conservation R&D	Total Energy R&D	Conservation as Percent of Total Dollars
France (FF)	N/A	4,825.0	N/A
West Germany (DM)	194.1	2,951.4	6.6
United Kingdom (£)	8.2	218.6	3.8

Source: CEC, Eurostat, Government Financing of Research and Development, 1984 Preliminary Data.

Although the statistical years of comparison are different for IEA and CEC data, some comparisons can be made. For instance, according to the CEC data, West Germany devoted 6.6% of total energy R&D funds to energy conservation R&D in 1984. In 1985, the IEA reports only 2.6% of total energy R&D funds allocated to energy conservation R&D. Conversely, the CEC reports that the United Kingdom spent just 3% of its 1984 budget for energy conservation while, according to IEA data, this figure nearly tripled to 10.2% in 1985.

This perceived year-to-year change in emphasis in energy conservation R&D, when comparing IEA and CEC data, may be attributable to multiyear planning in the budgeting process or changes in energy R&D policy over time. The United Kingdom designated 1986 as "The Year of Energy Efficiency" and, therefore, the large increase in budget share by energy conservation R&D in 1985 might represent a "gearing-up" of conservation programs. Given the magnitude of these differences, it is more likely that there are real differences in measurement between the IEA and CEC data series.

Further investigation reveals some interesting intertemporal comparisons of IEA and CEC data. Table 4.3 is a comparison of IEA and CEC government expenditures for energy conservation R&D as a percentage of total energy R&D. In the IAEA data the percentage of total energy R&D budget devoted to conservation remains stable for both West Germany and the United Kingdom from 1984 to 1985. Therefore, it appears that the IEA is measuring the same energy R&D expenditure phenomena from one year to the next. The difference between IEA and CEC

TABLE 4.3. Energy Conservation R&D Expenditures as a Percentage of Total Energy R&D (%)

Country	CEC (1984)	IEA (1984)	IEA (1985)
West Germany	6.6	2.6	2.6
United Kingdom	3.8	10.4	10.2

Source: IEA, Energy Research, Development and Demonstration in the IEA Countries, 1984 Review, Tables 4.2 and 3.2.

reported data for West Germany and the United Kingdom, therefore, appears to be a result of differences in data collection and reporting methods.

This difference in reported expenditures extends beyond energy conservation R&D as a percentage of total energy R&D. Table 4.4 contains both CEC and IEA data for total energy R&D expenditures for West Germany and the United Kingdom. As can be seen from this table, there are significant differences between expenditure figures reported by the IEA and CEC. In 1984, total energy R&D expenditures reported by the CEC for West Germany are nearly twice those reported by the IEA. The reverse is true of the United Kingdom where IEA-reported data exceed that of the CEC by nearly one-third.

As noted above, there are indeed differences in data collection methodologies between the IEA and CEC. The IEA specifically requests members not to include basic research in the R&D expenditure figures unless this research can be directly attributed to energy conservation. The CEC, on the other hand, requests no such exclusion. This may help to explain why expenditure figures for West Germany as reported by the IEA are substantially less than CEC data. West Germany, like the United States, devotes a good deal of resources to basic research, and while these expenditures are probably captured by the CEC data, they are purposefully excluded from the IEA data.

Likewise, the IEA instructs member countries to include "demonstration" programs (RD&D) in the R&D expenditure figures. This is not true of CEC data,

TABLE 4.4. Comparison of Expenditures for Total Energy R&D (Millions of National Currencies)

Country	CEC (1984)	IEA (1984)	IEA (1985)
West Germany (DM)	2,951.4	1,748.3	1,615.4
United Kingdom (£)	218.6	285.4	283.6

Source: CEC, EUROSTAT, Government Financing of Research and Development, Preliminary Data, and IEA, and Energy Policies and Programs of IEA Countries, 1985 Review.

however, where funds for demonstration are not included in research and development activities. This difference in methodologies may be the reason why IEA data for the United Kingdom, where demonstration is a key feature of the energy conservation RD&D program, exceed the CEC data.

Since the U.S. energy conservation R&D program, like the West Germany's, is focused towards basic research, CEC data may represent a better comparison for the United States and West Germany. Using 1984 CEC data as a surrogate for 1985 expenditures for energy conservation R&D requires inflating the currency to 1985 levels. The 1984 government expenditure data for energy conservation R&D, as reported by the CEC, were 194.1 million DM for West Germany and £8.2 million for the United Kingdom (see Table 4.2). Using IMF GDP inflators yields a 1985 figure of 198.2 million DM for West Germany and £8.7 million for the United Kingdom.

Next, these national currencies must be converted to U.S. dollars using average 1985 exchange rates (IMF). Following this procedure yields a figure of $67.4 million for West Germany in 1985. This is significantly larger than the $14.2 million reported by the IEA.

Using this same currency conversion procedure for the United Kingdom, a figure of $11.3 million is derived. This is substantially smaller than the IEA figure of $37.1 million reported in Table 3.2. The reasons for this, as noted above, may be the emphasis within the United Kingdom towards demonstration programs that would be included in IEA data but purposefully excluded from CEC data.

4.3.3 Domestic Data Sources

Table 4.5 contains both domestically obtained data with the IEA data presented in the previous chapter. Domestic sources of data for government expenditures for energy conservation R&D were uncovered for all countries except the United Kingdom. A discussion of the sources of these data and how final figures were derived is reserved for the Appendix.

TABLE 4.5. Government Expenditure Data as Reported by Domestic Data Sources

Country	Domestic Sources	IEA
United States	173.5	173.6
France	27.3	N/A
Sweden	24.2	22.3
West Germany	16.9	14.2
Japan	43.0	12.3

Source: IEA and Appendix.

5.0 COMPARISONS USING IEA AND ALTERNATIVE DATA

This section makes comparisons of government expenditures for energy conservation R&D using all available sources of data. High and low estimates of expenditures were established and comparisons were made of both absolute and relative expenditure levels. The methodology used for these comparisons is the same as used in Section 3.0.

5.1 HIGH AND LOW ESTIMATES

It was possible to obtain more than a single estimate of government expenditures for energy conservation R&D for most of the countries. One source of data for all the countries (except France) has been the IEA published statistics. Other estimates of expenditures were also derived in Section 4. Table 5.1 contains the two extreme estimates of expenditures derived from these sources.

In two (United States and United Kingdom) of the six countries studied, IEA data represent the high estimate for government expenditures for energy conservation R&D. IEA data represents the lower expenditure figure for the rest of the countries except: the United States, which is a domestic source;

TABLE 5.1. Government Expenditures for Energy Conservation R&D (Millions of 1985 U.S. Dollars)

Country	High Estimate	Low Estimate	Percent Change Between High and Low Estimate
United States	173.6*	173.5	0.06
United Kingdom	37.1*	11.9**	311.76
France	27.3	27.3	0.00***
Sweden	24.2	22.3*	8.52
West Germany	69.8**	14.2*	491.55
Japan	43.0	12.3*	349.59

Sources: IEA (*), CEC (**), and domestic data sources (see Appendix), (***) only one estimate available for France.

and, the United Kingdom, which is derived from CEC data. The CEC is also used as the high estimate for West Germany, while domestic data sources represent the high estimates for the remaining countries. Only a single estimate of expenditures was obtainable for France and this figure is used for both the high and low estimate.

As can be seen from Table 5.1, the difference between the high and low estimates varies from as little as 0.06% for the United States to as great as 491.55% for West Germany. The relative magnitude of the difference between the high and low estimate for Japan (349.59%) and the United Kingdom (311.76%) is also great. The difference between the high and low estimate for Sweden, however, is only 8.52%.

As noted above, IEA data represent one of the two estimates for both the United States and Sweden. The reason for the relatively wide spread in expenditure figures for all countries except the United States and Sweden (France obviously not included) may be that these two countries structure their national programs in energy conservation R&D in a manner that corresponds to IEA data collection and reporting methodologies. Conversely, the correspondence between the IEA data reporting methodology and the German, and especially the Japanese, energy conservation R&D programs is not so keen. This may help to explain the wide differences in the high and low estimates in these two countries.

Unfortunately, it is not possible to assign any confidence to either the high or low estimates in Table 5.1. Whether one number is more believable than the other largely depends upon the choice of definition for energy conservation R&D. Whereas the IEA data may be internally consistent from one year to the next for a single country, it is not possible to say that IEA expenditure figures are comparable across countries given the evidence in Table 5.1.

5.2 EXPENDITURES PER TOTAL PRIMARY ENERGY REQUIREMENT

Table 5.2 presents energy conservation R&D expenditures per Total Primary Energy Requirement (TPER). Since both the expenditure data from Table 5.1 and the TPER from Table 3.2 are in millions, the units in Table 5.2 are in

TABLE 5.2. Energy Conservation R&D Expenditures Per TOE (Dollars per TOE)

Country	High Estimate	High Rank	Low Estimate	Low Rank
Sweden	0.49	1	0.45	1
West Germany	0.26	2	0.05	5
United Kingdom	0.19	3	0.06	4
France	0.14	4	0.14	2
Japan	0.11	5	0.03	6
United States	0.10	6	0.10	3

Source: Tables 3.2 and 5.1.

dollars per TOE. When considering the high estimate for R&D expenditures, Sweden ranks first in energy conservation research dollars per ton of oil equivalent of TPER. Sweden is then followed by West Germany, the United Kingdom, France, Japan, and finally the United States.

The order changes when considering the low estimate for government expenditures for energy conservation R&D. In this case, Sweden is once again first but France moves to second ahead of the United States. The United Kingdom is next followed by West Germany and lastly Japan.

5.3 EXPENDITURES AS A PERCENTAGE OF GROSS DOMESTIC PRODUCT

Table 5.3 presents energy conservation R&D expenditures as a percentage of GDP of the six nations. Since the R&D expenditures are in millions of dollars and the GDPs are in billions of dollars, the percentages are quite small. Once again, using the high estimate, Sweden (0.024%) is first and West Germany (0.011%) second in government expenditures for energy conservation R&D expenditures as a percentage of GDP. These two are followed in order by the United Kingdom, France, the United States and Japan.

Like R&D expenditures per TPER, the rank order of the countries is altered using the low estimate for government expenditures for energy conservation R&D. Sweden (0.022%) is first, and France (0.005%) is second with the

TABLE 5.3. Energy Conservation Expenditures as a Percentage of GDP (%)

Country	High Estimate	High Rank	Low Estimate	Low Rank
Sweden	0.024	1	0.022	1
West Germany	0.011	2	0.002	5
United Kingdom	0.008	3	0.003	4
France	0.005	4	0.005	2
United States	0.004	5	0.004	3
Japan	0.003	6	0.001	6

Source: Tables 3.2 and 5.1.

United States (0.004 percent) third. The remainder of the countries (United Kingdom, West Germany, and Japan) follow in a similar fashion although the differences separating the countries appear to have tightened somewhat.

5.4 EXPENDITURES AS A PERCENTAGE OF THE CENTRAL GOVERNMENT BUDGET

Government expenditures for energy conservation R&D as a percentage of total government expenditures appear in Table 5.4. As in the case of Table 5.3, the percentages tend to be quite small due to the relative magnitude of the

TABLE 5.4. Energy Conservation R&D Expenditures as a Percentage of Total Government Expenditures (%)

Country	High Estimate	High Rank	Low Estimate	Low Rank
West Germany	0.080	1	0.016	4
Sweden	0.052	2	0.048	1
France	0.025	3	0.025	2
United Kingdom	0.020	4	0.006	5
Japan	0.020	4	0.006	5
United States	0.018	5	0.018	3

Source: Tables 3.2 and 5.1.

expenditure figures. The rank ordering of the countries is somewhat different, with West Germany (0.080%) now first and Sweden (0.052%) falling second. The United States is last among the leading OECD countries behind France, the United Kingdom, and Japan.

The low estimate for government expenditures for energy conservation R&D as a percentage of total government expenditures tells a somewhat different story also. Sweden (0.048%) tops the list of countries, followed by France (0.025%) the United States, and West Germany. Japan and the United Kingdom (both 0.006%) are last.

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APPENDIX

DOMESTIC DATA SOURCES

APPENDIX

DOMESTIC DATA SOURCES

A.1 UNITED STATES

The Office of Conservation within DOE oversees the government energy conservation program. As noted in Chapter 3 (see Table 3.1), the U.S. energy conservation program closely parallels the IEA data reporting structure. Therefore, one would expect to find a good correlation between data from U.S. domestic sources on government expenditures for energy conservation R&D and data reported by the IEA.

Three sources of data for energy conservation R&D expenditures are identified for the United States. First is the Congressional Record (CR) which contains historical and estimated budget authorizations for various agency programs. The historical budget authorization for Fiscal Year 1985 from the Congressional Record (12/19/85) appears as column one of Table A.1.

The National Science Foundation (NSF 1986a) also reports U.S. government budget authorizations for R&D funding. The sources for these data are

TABLE A.1. U.S. Energy Conservation-Related R&D Expenditures, Fiscal Year 1985 (Millions of 1985 US Dollars)

Program	CR	NSF	DOE
Building and Community Systems	41.4	40.0	41.0
Industrial	31.9	30.0	31.7
Transportation	61.8	56.0	61.3
Multisector	23.9	22.0	23.8
Facilities	--	--	15.7
Total	159.0	148.0	173.5

Sources: NSF, Federal R&D Funding by Budget Function: Fiscal Years 1985-87, March 1986, p.56 the Congressional Record, December 19, 1985, p.H13007; and, U.S. DOE FY 1987 Congressional Budget Request, Energy Conservation, Volume 7.

the Exhibit 44s which are part of the federal government agency submissions to the U.S. Office of Management and Budget (OMB). Other sources of data are mentioned, but not specifically cited. The R&D expenditure data for energy conservation appear as column two of Table A.1.

In most cases the differences in expenditure figures between columns one and two can be attributed to rounding of numbers by NSF. Further examination of CR data revealed $1.9 million for program direction and $2.9 million for capital equipment within the Transportation program which was not included in the NSF figures.

Finally, DOE prepares an annual budget submission that contains both historical and projected expenditure data (U.S. DOE). This data appears as column 3 of Table A.1. The main difference between this data source and the other two is an additional line item for "facilities" which totaled $15.7 million for 1985. The total for column 3, Table A.1 compares favorably with the $173.6 million of reported expenditures for the United States by the IEA (see Table 3.2).

A.2 FRANCE

A large number of government organizations conduct energy conservation R&D in France. However, the French Energy Management Agency (AFME) is responsible for managing and coordinating all government energy research. Energy research programs receive multiyear funding to maintain continuity in the research effort.

Table A.2 shows French energy conservation-related expenditures for the fiscal years 1983 through 1985. Of the fourteen program areas, only the Heat Storage program does not coincide with the United States' definition of energy conservation. Subtracting the 35 million FF from the total of all programs yields a figure of 645 million FF for the three-year period.

Expenditure figures were not available for individual years (Chartier). Since there is no way to determine the share of expenditures attributable to any one year, a simple arithmetic average of the three years is used. In this manner, one-third, or 215 million FF, is representative of French government expenditures for energy conservation in 1985. This methodology may

not result in a serious loss of information since the French do employ multiyear funding authorizations for R&D projects.

The figures in Table A.2 are in 1983 FF for all three years of funding. Before converting to U.S. dollars, it is necessary to inflate these figures to 1985 levels. Using a GDP inflator (IMF) of 1.14 would raise the three-year average figure to 245.1 million in 1985 FF.

Converting the 245.1 million FF to U.S. dollars using an average 1985 exchange rate of 8.98 FF to the dollar (IMF), yields a final figure of $27.3 million for energy conservation R&D in 1985. Since only one source of expenditure data was found for France, there is no way to validate these data.

TABLE A.2. French Energy Conservation-Related R&D Expenditures Fiscal Years 1983 Through 1985 (Millions of 1983 FF)

Program	FF
Agriculture	43
Economical Vehicles	125
Equipment and Components	28
Batteries	20
Engines	16
Various Transports	29
Processes	67
Exchanges	50
Rational Use of Electricity in Industry	40
Various Industry	46
Air Management and Bioclimatic Insulation	90
Heat Generators	39
Heat Storage	35
Various Housing	52
Total	680

Source: AFME, La Recherche et le Developpment a l'AFME, May 5, 1986

However, compared with IEA data for other countries, France would be seen as falling between the United Kingdom ($37.1 million) and Sweden ($22.3 million) in terms of gross expenditures.

A.3 WEST GERMANY

West Germany has an active program in energy conservation R&D. The Federal Ministry for Research and Technology (BMFT) is responsible for overseeing research activities funded by the central government. To aid in this administrative process, the BMFT established and maintains a database of R&D projects and related expenditures. These project finance data also appear in the annual report on the program for energy research and technologies (BMFT).

The Datenbank Vorhaben (Project Database) contains several years of data for various energy research and development projects, including energy conservation. Table A.3 presents energy conservation-related R&D programs with the associated budgets for FY 1985. The program definitions are provided by the Office of Renewable Energies and Efficient Energy Use, BMFT. The total of DM 63.6 million in Table A.3 compares well with the DM 62 million (less hydrogen research) reported by the BMFT (BMFT) and also DM 68 million (probably including hydrogen research) from the detailed government research budget (NTIS).

Of the five program areas listed in Table A.3, all but one (Energy Storage) is directly related to the U.S. energy conservation programs. Some of the research within Energy Storage might correspond to similar research managed by the U.S. energy conservation program. However, without more detailed analysis it is not possible to determine the amount.

Subtracting the approximately DM 13.9 million attributable to the Energy Storage program from the total in Table A.3 leaves DM 49.7 million designated as energy conservation R&D expenditures for 1985. This figure can be converted to U.S. dollars using an average 1985 exchange rate of DM 2.94 to the U.S. dollar (IMF). Following this procedure yields a total of $16.9 million for energy conservation R&D funded by the West German government in 1985.

TABLE A.3. West German Energy Conservation-Related R&D Expenditures Fiscal Year 1985 (Millions of 1985 DM)

Program	DM
Electricity and Heating, including: - district heating (DH) - cogeneration - heat pumps for DH - generation of electricity - transportation of electricity - industrial waste heat for district heating - capacity load management - local and regional concepts for energy - supporting measurements	12.8
Rational use of energy in industry, including: - heat exchangers - motor research	30.5
Energy Storage, including: - electric batteries - heat storage systems - mechanical storage systems	13.9
Rational use of energy in the building sector, including: - insulation material - controlled air regulation - conventional heating system research	4.8
Heat Pumps, including: - electric driven HP - gas and diesel HP - absorption HP	1.6
Total	63.6

Source: BMFT, Datenbank Vorhaben (DAVOR) Database, January 12, 1986.

This $16.9 million figure is reasonably close to the $14.2 million reported by the IEA. However, both are far short of the $67.4 million derived from CEC data sources in Section 4.3.2. As previously mentioned, this difference is more than likely because CEC data includes basic research which is excluded from the IEA data.

A.4 SWEDEN

Several government agencies undertake energy conservation R&D in Sweden (Energy Research and Development Commission, October 1986). However, the Energy Research and Development Commission (DfE) has responsibility for coordination of R&D efforts in the energy field. Data obtained from the DfE on several major R&D programs appears in Table A.4.

All the activities within the Industrial and Transportation programs seem to be consistent with the U.S. energy conservation program. Some R&D activities within the other major program areas exhibit less overlap. Therefore, each of these activities must be examined more closely to determine their appropriateness for inclusion with energy conservation R&D.

In the Buildings program, Solar Heating Technology would be considered renewable energy according to the U.S. definition. Likewise, Heat Sources and Energy Storage would also be outside energy conservation. Energy Systems is less obvious, but since the focus is buildings, this is included in energy conservation. Both Heat Pumps and possibly Heat Distribution Systems are energy conservation-related and should therefore be included.

Energy Supply would not normally be considered in a discussion of energy conservation R&D. However, Sweden has chosen to place both District Heating and Combustion Technology in this program area. Therefore, expenditures for these two programs must be included in the total for energy conservation in order to be consistent with the U.S. program.

Long-Term Research and Fundamental Research comprises nearly one-tenth of total R&D funds listed in Table A.4. This research includes catalysis, tribology, biomass, and environmental impacts of energy use (DfE). Since no breakout is available for individual projects, a simple proportional method is used to apportion fundamental research in the area of energy conservation. One fourth, or 7.5 million SEK, is used based on the IEA (see Table 3.2) proportion of energy conservation research to total energy R&D for Sweden.

Summing the program areas identified above yields a total of 207.9 million SEK for energy conservation in 1985. Using an average 1985 exchange rate of 8.60 SEK to the U.S. dollar, this would be $24.2 million. This is slightly larger than the $22.3 million reported by the IEA.

TABLE A.4. Swedish Energy Conservation Related R&D Expenditures Fiscal Year 1985 (Millions of 1985 SEK)

Program	SEK
Energy Use in Industrial Processes	
Pulp and Paper	22.0
Iron and Steel	31.3
Common Energy Techniques	33.0
Energy Use for Transportation	
Transportation Systems	4.0
Energy Use in Vehicles	28.0
Energy Use for Buildings	
Solar Heating Technology	6.7
Heat Pumps	12.3
Heat Sources	5.6
Energy Storage	5.8
Heat Distribution Systems	5.1
Energy Systems	3.1
Energy Supply	
District Heating and Heating Efficiency	10.5
Combustion Technology	44.6
Fuel Conversion	24.4
New Technologies for Electricity Production	9.5
Advanced Technologies	20.8
Long-Term Research and Fundamental Research	30.2
Total	296.9

Source: Energy Research and Development Commission, Sweden.

A.5 JAPAN

There are two ready sources of data for government expenditures for energy conservation R&D in Japan. The first source of data is the budget of the Moonlight Project,(a) the Japanese government's premier conservation research program. The Moonlight Project is managed by the Agency for Industrial Science

(a) The name "Moonlight Project" is a connotation of the idea that even the smallest amount of energy (moonlight) will be used effectively. There is also a "Sunshine Project" for renewable sources of energy.

and Technology (AIST) within the Ministry for International Trade and Industry (MITI). Table A.5 details the program areas and appropriations for the Moonlight Project in FY 1985.

There are some programs within the Moonlight Project that are outside energy conservation R&D as defined by DOE. For instance, in the United States fuel cell and battery electric power storage are administered through the renewable energy program. Deleting Fuel Cells and Electric Power Storage from the Moonlight Project leaves a total of 4,169 million yen.

An attempt has been made to sort through a host of Japanese research programs for energy conservation-related R&D expenditures (Howard). C. D. Howard (PNL) identified programs within Basic Technologies for Future Industries, New Energy Development Organization (NEDO), Ministry of Science, Education, and Culture (MESC), and the Science and Technology Agency (STA) ERATO. Table A.6 presents the program descriptions and budget authorizations of these programs.

TABLE A.5. Japanese Energy Conservation Related R&D Expenditures, Fiscal Year 1985 (Millions of 1985 Yen)

Project	Yen
Advanced Gas Turbine	1,207
Advanced Battery Electric Power Storage System	2,201
Fuel Cell Power Generation Technology	4,776
Stirling Engine	1,673
Super Heat Pump Energy Accumulation System	607
Leading and Basic Technology for Energy Conservation	227
International Cooperation in R&D	20
Technology Assessment	69
Subsidization for Energy Conservation Promotion	140
Subsidization for Development of Equipment for the for the private sector	55
Total	11,146

Source: The Ministry for International Trade and Industry (MITI).

TABLE A.6. Japanese Energy Conservation-Related Programs

Program	Million Yen
BASIC TECHNOLOGIES FOR FUTURE INDUSTRIES	3,968
- High-Performance Ceramics	961
- Advanced Composite Materials	721
- Advanced Alloys	610
- Synthetic Membranes	556
- Bioreactors	446
- Synthetic Metals	375
- High-Performance Plastics	299
NED0400	
- Methanol Utilization	400
MESC: UNIVERSITIES	190
- Combustion and Laser Diagnostics	190
STA: ERATO	1,524
- Amorphous Metals and Intercalation Compounds	459
- Ultrafine Particles	349
- Superbugs	329
- Fine Polymers	247
- Solid Surfaces	140
Total	6,082

Source: AIST, 1985; Landgrebe, January 1986; Committee on Laser Diagnostics and Prediction of Combustion, 1986; "ERATO Looks to Other Countries," September 16, 1985.

The programs in Table A.6 total 6,082 million yen. Adding this to the adjusted Moonlight Project figure of 4,169 million yen yields a total of 10,251 million yen. This figure may tend to overstate government expenditures in Japan since it has not been determined what portion of the projects listed in Table A.6 are energy conservation-related and what portions represent research in medicine, agriculture, and other areas.

A third source of data for Japanese government expenditures for energy conservation R&D is the annual summary of Science and Technology Indicators published by the STA. This publication contains data for both public and

private expenditures for R&D, including a category for energy conservation. The most recent available data for detailed R&D expenditures is for 1984. This data is presented in Table A.7.

Of the six research areas listed in Table A.7, Hydrogen is the only one which can be readily excluded as not conservation-related. There are three performers of the research as identified in this table. They are: Industrial (private industry); Research Institutes (public and private); and, Universities (national, local, and private).

According to Japanese sources (Namiki, Japan Electric Power Information Center) no central government funds are expended with the Industrial performers in Table A.7. Although data do not exist as to the source of funding for the other two performers in 1984, this information does exist for 1983. Table A.8 contains the level of funding by source and percentage of total funding by performer in 1983.

TABLE A.7. Public and Private Expenditures for Energy Conservation R&D

	Research Organization			
Research Program	Industry	Research Institutes	Universities	Total
Industrial	41,127	2,669	1,555	45,351
Public Welfare	16,754	243	362	17,359
Transportation	61,074	96,663	714	158,422
Conversion and Storage of Electric Power	12,727	6,073	790	19,591
Hydrogen	2,386	492	481	3,358
Other	5,396	402	527	6,324
Total	130,205	11,944	4,428	250,404

Source: Indicators of Science and Technology Indicators, Science and Technology Agency (STA), Japan, 1985.

TABLE A.8. Energy Conservation Funding by Source, 1983 (Million of Yen)

	Research Performer			
Funding Organization	Research Institutes	Percent	Universities	Percent
Central Government	4,835	(5.24)	3,234	(74.57)
Local Government	1,004	(1.09)	132	(3.04)
Private Sector	86,367	(93.54)	971	(22.39)
Special Organization	128	(0.13)	0	(0.00)
Total	92,333	(100.00)	4,337	(100.00)

Source: Mr. Toru Namiki, Japan Electric Power Information Center, March 1987.

Assuming that the proportion of funding by source was the same in 1984 as in 1983, then central government funding of research institutes would be 3,301.9 million yen and university funding 625.9 million yen. Inflating the total of 3,927.8 million yen to 1985 levels the combined funding would be 4,006.4 million yen. This is reasonably close to the adjusted budget of the Moonlight Project of 4,169 million yen.

Converting the figures to U.S. dollars using an average 1985 exchange rate of 238.54 yen to the U.S. dollar the adjusted budget of the Moonlight Project (less Fuel Cells and Advanced Battery Research) yields a figure of $17.6 million. The same figure from the procedure used by Howard would be $43.0 million. Both of these expenditure figures are greater than the $12.3 million reported by the IEA.

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