Energy Technologies for the 21st Century

Energy Research, Development and Demonstration Expenditure 1985-2000: An International Comparison

A Report by a Study Group of the World Energy Council

August 2001

ENERGY TECHNOLOGIES FOR THE 21ST CENTURY

ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION EXPENDITURE 1985-2000: AN INTERNATIONAL COMPARISON

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FOREWORD

Late in 1999, WEC launched a major study designed to advance energy technology and efficiency in the 21st Century. There was a strong view, emanating from the World Energy Congress in Houston in September 1998, that new technology innovation and more rapid deployment of improved technologies were required to widen commercial availability of modern energy services, to accelerate efficiency improvements, and to tackle a range of environmental issues from the local to the global. But, at the same time, there was a perception that the commitment to technology research and development by governments and private companies was weakening.

Under the chairmanship of Dr. Robert Schock of the United States, the Study Group considered that it had taken on a major challenge. First, there is no consistent historic data source for energy Research, Development and Deployment (RD&D) spending across countries – the International Energy Agency comes closest with data for government spending by some of its Member Countries. Second, when looking to the future, the question is not simply one of seeking to advance known technologies, even if some technologies seem robust across a range of scenarios; there is also a need to have a sound understanding of scenarios relating to possible energy futures, and of future technological breakthroughs which have not been widely or intensively explored before. The Group therefore altered the original plan so that a first phase of its work could be completed in time for the World Energy Congress in October 2001, leaving other work for a second phase in the 2002-2004 Work Cycle.

In the initial stages of the Study Group's deliberations, WEC published "Energy for Tomorrow's World—Acting Now!" which set goals to 2020 for commercial energy access, for the quality and continuity of energy supply, and for the management of energy-related emissions at the local, regional and global levels. One of the ten key actions cited is funding for research, development and deployment, with a focus on energy efficiency, renewables, carbon sequestration, cleaner fossil fuels, nuclear power and waste technologies, superconductivity, and integrated decentralized energy systems. It was confirmed that a clear picture of actual R&D spending (however coded or spent) and technologies which can deliver sustainable energy futures would be a major contribution to understanding and the international collaboration required in the years ahead.

Phase I of the work has been successfully completed. "Energy Research, Development and Demonstration Expenditure 1985-2000: An International Comparison" is a report prepared by Michael Jefferson of the United Kingdom, including case studies in key countries and regions of the world which remain the responsibility of the experts or WEC member committees which prepared them. A separate publication on "An Assessment of Technological Change Across Selected Energy Scenarios" zeroes in on robust power generation technologies; and on oil and gas extraction, and synfuel production, technologies. This part of the work was carried out by Nebojsa Nakicenovic and Keywan Riahi of the International Institute for Applied Systems Analysis in Austria.

The Study Group has proposed work to complement Phase I on technologies that were not studied in the first phase (carbon sequestration; transportation and end use technologies; strategies of private industry; and the role of governments). It is intended that this work be done in the 2002-2004 Work Cycle of the World Energy Council. This proposal will be considered by the Standing Committee on Studies and the Executive Assembly when they meet in Buenos Aires in October.

I want to thank the Study Group for Phase I, whose members are set out in Annex III, for their tireless efforts to gather relevant data on R&D spending and on energy technologies which will contribute effectively to the goals of energy accessibility, energy availability and energy acceptability and, therefore, sustainable development in every region of the world.

Gerald Doucet
Secretary General
August 2001

INTRODUCTION

Spending on research, development and demonstration (RD&D) has long been positively associated with the pace and quality of technological innovation in many sectors of human endeavour. In the field of energy, it is a widely held view that spending on RD&D is an important precursor to the technological advances required to secure sufficient, safe and environmentally-acceptable energy supplies, and to use them more efficiently.

Technological advances will be of critical importance in improving living conditions. Advances which improve the production and transportation of energy, and the efficiency of its use, may be expected to produce major public benefits which warrant governmental support, including funding and other incentives for private sector efforts.

We live in a world where the population is growing, where many of those in developing countries still do not have access to modern energy services, and where the impacts of pollution and greenhouse gas emissions are (or should be) of rising concern. The need to ensure that progress in advanced fossil fuel technologies, in non-fossil fuel technologies, and in energy efficiency technologies is maintained and accelerated is widely accepted in the energy sector as one of the key responses to these challenges. For this reason, the World Energy Council (WEC) takes a close interest in the subject, and decided to undertake this study. Governments, international organisations, energy end-users and all those concerned with the environmental impacts of energy use should have a similar interest.

WEC's decision to carry out this study was spurred by reports of widespread declines in energy RD&D spending since the early 1980s. These reports took various forms:

- Energy-related RD&D expenditures were dangerously low in relation to other technology-intensive economic sectors.
- Public sector (governmental) energy-related RD&D expenditures were in rapid decline.
- Overall energy-related RD&D spending was falling everywhere.
- In the USA it was noted that, whereas primary energy and energy services account for around 8% of GDP, energy RD&D spending by government accounts for only some 3% of total RD&D expenditure. Such discrepancies could be widespread in other countries.
- Countries were becoming more vulnerable to the emerging risk of global climate change, even if some were succeeding in the abatement of the adverse health and local environmental impacts of energy use.[1]

The concerns raised by these reports were reinforced by comments on the causes and consequences of general budgetary constraints on governments:

- The selling-off of public sector companies or their assets to raise revenue.
- The liberalisation of energy markets to encourage competition and therefore economic efficiency.
- Consequent claims that a decline in long-term thinking and strategic planning had occurred, evidenced by a reduction in expenditure on RD&D of the sort previously supported by some former state-owned enterprises[2]. However, suggestions that politicians or governments may now be more short-term

oriented than previously, or that former state-owned enterprises which were not tightly focussed on customer service and shareholder value demonstrated long-term thinking and strategy, have been roundly rejected.

There were, however, other reports which suggested that these conclusions were not necessarily correct. These included reports that:

- Too much might be read into data on governmental RD&D expenditure (which is readily available from the International Energy Agency), whereas private sector RD&D spending did not (or might not) follow this pattern.
- The marked declines in overall RD&D expenditure in some countries were not matched in some other countries.
- Declines in RD&D in some sub-sectors (such as nuclear fission – much of which had been conducted for regulatory reasons – and conventional fossil fuel technologies) were not matched in other sectors – such as renewable energy, advanced fossil fuel technologies (including carbon sequestration), and energy conservation.[3]
- The sharp decline in crude oil prices from late 1985, with an only partial recovery a year later, discouraged RD&D expenditure both in non-fossil fuel technologies and in some areas of fossil fuel activity (for example, RD&D efforts aimed at bringing down exploration and production costs, or raising efficiency, no longer seemed to have the same urgency).
- While some arguments could be brought forward to justify the reduced RD&D spending on traditional fossil fuel and nuclear fission technologies which had apparently occurred, other arguments could be advanced to justify maintaining or increasing RD&D spending on renewable energy and carbon sequestration, as had occurred in several countries. In other words, the outcome in most of the countries surveyed had been rational.

There were also some more technical questions raised in these sceptical reports. There are serious problems in making international comparisons of energy RD&D expenditure. There are problems of defining what is included in RD&D, both between countries and, over time, within them. There are severe difficulties in obtaining private sector energy RD&D spending data.

Furthermore, spending is severely skewed between countries – the USA and Japan account for over 65% of the energy RD&D spending by International Energy Agency (IEA) member governments. Such spending – and its decline where demonstrated – is also heavily skewed in favour of nuclear fission and fusion (which accounts for over 50% of total energy RD&D expenditure by IEA member governments). The rationale for spending on nuclear fission RD&D is, however, significantly different to that for nuclear fusion (which has attracted substantial international collaboration).

Perhaps no less important than any of these considerations, there is also no clear way of measuring the value of RD&D spending. Inputs do not necessarily equate with outputs. RD&D spending by major energy companies may have fallen, but there seems to be evidence that energy service and technology companies have tended to maintain, and sometimes increase, their RD&D expenditure. Advances in electronic data processing and telecommunications systems may also have had a significant – but so far unmeasurable – positive impact on the productivity of RD&D spending.[4]

Given these varying and sometimes conflicting reports, WEC decided to try to find out what was actually happening. It was felt that the uncertainty about RD&D resulting from these varying reports was a cause for concern, given the importance of technological development in meeting the future challenges of availability and quality of energy services, satisfaction of basic needs, maintaining environmental quality and protecting ecosystems.

Appropriate RD&D, technological innovation and the diffusion of new technologies within society are generally believed to be of great importance for human progress. There are many influences on each of these – perceived needs, economic conditions, environmental problems or threats, pricing and taxation policies, rewards to innovators and developers – any and all of which may be important. The size and composition of recent RD&D expenditure may be considered more or less appropriate to the future challenges and opportunities which are anticipated.

Energy RD&D expenditure may be regarded as a form of insurance against possible impacts such as rapid global climate change, and estimates have been made of its value.[5] Ideas may exist about the more robust technologies relevant to possible future developments, which current RD&D spending may or may not match well.[6]

In short, this study was motivated by the belief that we need to know what has happened to RD&D. Chapter 1 sets out what the Study Group has tried to do, how it has tried to do it, and some of the known pitfalls. Chapter 2 provides some overall findings, and in subsequent chapters RD&D spending by main fuel sources, plus efficiency and conservation, is considered. The report also includes the Study Group’s conclusions and recommendations. The Annexes contain the most comprehensive country reports which were provided for the study. The membership of the Study Group is given in Annex III.

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1. GOALS, PITFALLS AND METHODOLOGY

In preparing this report, the Study Group has tried to discover the facts about energy-related RD&D expenditure since 1985 in those countries for which comprehensive data could be obtained. Such data was sought for over 40 countries, and originally the Study Group hoped to obtain them for over 20. WEC Member Committees, other national sources, and some international organisations were approached in an effort to obtain comprehensive information. In the event, only nine country reports were obtained – for Austria, Denmark, Finland, France, Japan, Republic of Korea, Spain, Sweden and the USA. Five of these reports were quite comprehensive.

The Study Group was also kindly provided with a special report for this study by the European Commission’s Research Directorate (ENERGIE Programme). In addition we obtained some data for two industrialised countries and four developing countries - Germany, Mexico, Pakistan, South Africa, Swaziland and Switzerland. The data on these two industrialised countries had already been published elsewhere, and therefore have only been briefly evaluated in this report.

We have also drawn on published sources and electronic databases, both national (for example, for Germany and Switzerland) and international (the International Energy Agency (IEA) Energy Technology R&D Statistics Service). However, such sources almost invariably cover public sector (governmental) energy RD&D spending only. They do not include private sector spending. The Study Group has sought to rectify this in the country reports which appear in the Annexes, and in the following chapters.

RD&D is defined here as encompassing basic and applied research through to feasibility testing and small scale deployment. Energy RD&D we define as basic and applied research, as well as technology development and demonstration, in all aspects of:

- resource extraction and production (from exploration through drilling or mining to refining);
- power generation (whether from fossil fuels, renewable sources of energy, nuclear fission or fusion);
- transmission, distribution and energy storage;
- energy efficiency and conservation;
- end-use technologies;
- carbon separation, capture and sequestration.[1]

This array of activities has recently been given the shortened form “ERD^3” (Energy Research, Development, Demonstration, and Deployment).[2]

The comprehensive country reports prepared for this study have sought to apply this definition, but there is no universally accepted definition. Neither do energy RD&D data series usually provide detailed classifications, nor do they usually attempt to ensure compatibility between series. Even in the USA, the only official surveys of private industry spending on energy RD&D (by the National Science Foundation) provide a “most cursory” definition of energy RD&D and “there is no way of knowing what kinds of energy technologies are being developed by industry through looking at this data set”.[1] These surveys also exclude energy RD&D carried out by non-profit organisations, a vacuum which other organisations – the Electric Power Research Institute and the Gas Technology Institute – can only partially fill.

To this catalogue of problems can be added the difficulties of knowing what venture capitalists and start-up industrial firms are doing, which may include research, development and/or deployment. A reading of financial analysts' reports suggests this could be an important area, and yet information is largely anecdotal.[3]

In fact a wide array of activities can be classified as energy RD&D, at least in part. Apart from the obvious categories mentioned above, there are some less obvious ones:

- Military R&D which has energy 'spin-offs' (for instance, relating to improved aircraft engine performance, which subsequently leads to improved natural gas-fired turbines) may be important but is usually excluded.
- Research into catalysts and materials science.
- New chip designs which improve battery life for various applications.
- Fibre optic research, which permits utilities to deliver cable television to homes.
- Research into portable fuel cells to power laptop computers.
- Space agency investments in photovoltaic cells used in communication satellites.
- Long-term research into beaming solar power from space to terrestrial receivers for electricity generation.
- Government-funded programmes to accelerate the deployment of efficient heat pumps – which can be justified on conservation or energy generation grounds (for example, in district heating schemes in Sweden).
- Government-funded research into reducing traffic bottlenecks.
- Research into consumer attitudes towards 'green power'.
- Automobile industry research.
- Research into carbon cycle modelling.

There are also significant definitional problems when energy companies invest in research more closely related to 'step-out' activities than to their main business. For instance, funding by a pharmaceutical subsidiary of research into a cancer cure, or research conducted by a metals subsidiary. Furthermore, an energy company's mainstream RD&D function may be engaged in work which seems more closely related to improving corporate standing with the general public or the investment community, than with advancing scientific understanding or technology diffusion.

Frequently RD&D expenditure is simply defined as spending within a particular budget category. The US White House Office of Management and Budget defines energy RD&D as all activities contained within budget category 270. Research organisations, including industrial research associations, often define energy RD&D as simply their budgets.

This lack of clarity and consistency is not helpful to an understanding of the real level, purpose and effectiveness of energy RD&D spending. We have sought to avoid casting the net too wide, but any success can only be limited. Furthermore, even where there is some confidence about a category and its definition, there may be limits to the value of knowing whether spending is going up or down. For example, if expenditure on nuclear fission has gone down, is this due to a withdrawal from a fast breeder reactor programme, waste recycling or storage, a core part of a light water reactor programme, or what? If expenditure has gone up, does it herald something fundamentally new or an attempt at more of the same?

Comparisons are also made much more difficult when energy RD&D expenditure in different countries is converted to a common currency (such as US dollars), and this problem is exacerbated when market exchange rates are applied rather than purchasing power parities. One consequence of this, it has been claimed, is that Japan's energy RD&D expenditure is inflated relative to that of the USA.[4]

The major published work on governmental energy RD&D spending is *IEA Energy Technology R&D Statistics, 1974-1995*, published by the OECD/IEA in 1997. The data are presented for 22 IEA member countries in US dollars (1995 prices and exchange rates) only. In this report, we have used the IEA's Energy Technology R&D Statistics for national currencies at 1999 prices, available on the IEA's electronic database, on the assumption that governments are the most appropriate source for constant price deflators. However, for the country reports published in this report nominal national currencies have been preferred. It is important that consistent approaches are taken in converting nominal values into constant terms, and in converting to a common currency at purchasing power parity.

Another set of problems arises with a lack of inclusiveness of energy RD&D data. In some countries, government energy RD&D spending may not include spending by government laboratories, or publicly-funded university research. Private sector energy RD&D expenditure data are particularly difficult to obtain. This includes corporate spending, non-profit research laboratories (often linked to industry associations), and research by special interest groups – for instance, wind or solar energy industry associations.

In a few countries, regular annual surveys are undertaken of private sector energy RD&D expenditures by government or under government mandate, but this is rare. There are occasional surveys from industrial groups. From time to time data from individual companies may be made available. But these surveys and data are usually intended for the finance community, and use published financial data. Thus the emphasis is on RD&D expenditure as a percentage of sales or per employee, which may not provide the information desired on what the money is actually being spent on.

Even where there are regular surveys of RD&D spending by both the public and private sectors, they may not be very helpful because they are organised by industrial branches rather than by expenditure on energy and other sectors. This may not matter so much for the power utilities branch, yet it fails to give enlightenment on energy-related RD&D spending by the manufacturing sector or for end-use technologies.

Many major energy companies, including those specialising in energy technology and services, also have international operations. Their energy RD&D expenditures may largely take place outside their home base or main markets, and risk being excluded in some data series. Or there may be such difficulty in tracking such expenditures across national boundaries that double-counting occurs. There is evidence that in some countries private sector energy RD&D expenditure has been falling in recent years, and that a sharp and sustained decline corresponds to efforts to deregulate the electricity sector in particular.[5] Others suggest that while this may be true for the utilities concerned, many of them have begun to outsource their research, with results for total energy RD&D expenditure that are difficult to estimate.

In an era of tougher competition, sharper focus on costs, and price regulation, it seems more likely that there has been a contraction of energy RD&D spending in the electricity utility sector. There is also evidence to suggest that the energy RD&D spending which is occurring is more heavily focused on elements expected to provide a competitive advantage, and away from projects which might claim to offer ‘public benefits’. Consolidation within the US oil and natural gas sector is claimed to be “clearly leading to a reduction in the scale of the oil and gas industry’s energy R&D”.[6]

Brief mention has already been made of the tendency to exclude from energy RD&D expenditure military spending that may produce major benefits to the energy sector. The example of turbines is not unique – the energy sector (among others) has been a major beneficiary of military spending programmes on materials, photovoltaic panels, batteries, and electronic data processing and communications. Cuts in military spending in many industrialised countries during the 1990s have been one of the factors behind reduced RD&D expenditure.

Definitions of government energy RD&D expenditure have also been subject to change. In the USA, there is the important example of the Basic Energy Sciences Budget being taken out of the federal energy RD&D spending totals, one cause of an apparent sharp slump in federal energy RD&D expenditure in 1997. The US President’s Committee of Advisors on Science and Technology (PCAST) was unable to review this budget item in detail when it considered federal energy R&D for the challenges of the twenty-first century in 1997.

Nor did PCAST review some other energy R&D budgets – such as “Energy Research: Other Non-Fusion”; “Other Nuclear R&D”; and “Other Conservation R&D” – which it dismissed as “containing mostly items that are either not very closely linked to advances in civilian energy technology or are not really R&D at all”.[7] It would seem important that energy RD&D expenditure definitions should be clear; should exclude items which “are not really R&D at all”; and should be changed infrequently, only if necessary, and in such a way that the impact of the changes can be readily traced.

For the new work contained in this report, most of which is set out in its original form in the Annexes, we sought to provide country reports produced to a common format. A very detailed list of eight headings and 35 sub-headings was provided for guidance to those reporting back. As indicated earlier, 47 countries were contacted; 21 responded, of which nine provided detailed reports or data. An additional six provided some data, as indicated earlier.

Distinctions between fossil fuel, non-fossil fuel, efficiency and conservation, exploration and production, distribution and storage, etc. were all intended to be handled in a uniform way. Not all the reports have succeeded in doing that, and not all contain the same amount of detail. More country reports would have been helpful, to ensure a representative picture. But the country reports which were obtained, because of the large contributions of the USA and Japan to the total, probably cover over 70% of total global energy RD&D expenditure. The Study Group believes this is therefore sufficient to permit some valid conclusions to be drawn. This assessment is based upon what is known about government energy RD&D spending in the major industrialised countries and a few others, and what can be guessed about private sector spending.

The next chapter presents the main overall findings to be drawn from the new country reports, together with other country data, information about European Union (EU) programmes, and an assessment of information to be found on the IEA's energy technology R&D database.

It is not the purpose of this report to comment on how far national and international collaboration on energy RD&D could be improved to global benefit, although it will already be clear that weaknesses in the data and lack of clarity about definitions themselves suggest there is much room for improvement. However, the Study Group does draw conclusions and make recommendations in the last two chapters of this report on the need for greater collaboration.

In its 1997 report, PCAST was critical of the lack of collaboration in the USA between the various federal applied energy technology programmes, and between them and fundamental research efforts. This may well be the case in other countries also. The wider and more ready sharing of research results and development/deployment experience would seem to be valuable in itself, by avoiding replication, reducing costs, and accelerating useful outcomes.

The same report pointed to the need for governments to address barriers to the commercialisation of innovative technologies, and for greater action where there are high potential pay-offs for society that justify bigger RD&D spending than the private sector would be expected to make on the basis of expected returns on its investment. This again is important and likely to have widespread validity.

The 1999 PCAST report focused on the scope for international cooperation on energy innovation, and how this might lower the cost and increase the pace of innovation for the USA. Again, this is likely to have more general validity – and links closely to many of WEC's longstanding concerns about widening access to modern energy services, improving their reliability and efficiency, and reducing their adverse environmental impacts. Some related studies by other bodies are also related to current WEC work.[8]

But important though both these wider and longer term issues are, the objective of this report is more confined: to shed light on what has *actually* been happening with energy RD&D expenditure in the period since 1985. If the lessons that can be drawn have wider implications and potential longer term significance, this will be an added bonus.

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2. MAIN FINDINGS FROM COUNTRY STUDIES

The main findings here are drawn from the country studies in the Annexes. They are summarised by country, listing the USA and Japan first because of the large size of their energy RD&D expenditure, followed by other countries for which data was obtained in alphabetical order. The report on European Union Energy Research and Technology Development is then summarised. This is followed by some remarks on total government energy RD&D expenditure taken from the IEA's energy technology database. There then comes a summary of sectoral RD&D expenditure. At the end of the chapter, the findings of this report are compared with those of some other country studies. These other studies are also used to comment on some countries for which no country report or data were made available to the Study Group: Canada, the Netherlands, Italy and the UK.

2.1 Total Energy RD&D Expenditure

2.1.1 Country Summaries

United States

- In constant 1995 US dollars, total energy RD&D expenditure has fallen fairly steadily (apart from a slight upturn in 1990-91) from US$7.4 billion in 1985 to US$3.7 billion in 1999. This is a fall of 50% in real terms, of which 11.5% took place between 1985 and 1986. Since the peak year of 1980, the fall has been 68%. At the national level, spending appears to have stabilised over the period 1997-99, but at a 26-year low. Chart 1 summarises this evolution.
- Energy RD&D expenditure in 1999 represented 0.042% of US Gross Domestic Product (GDP), down from 0.128% in 1985. In 1980 the figure was 0.231%.
- Private sector energy RD&D expenditure similarly fell quite steadily between 1985 and 1999, from just over US$4.1 billion to just under US$1.4 billion. That represents a fall in real terms of 66%, of which just over 15% occurred between 1985 and 1986.
- Public sector energy RD&D expenditure also fell, but rather less dramatically, from nearly US$3.3 billion in 1985 to just over US$2.3 billion in 1999. This was a fall in real terms of 29%, but there have been sizeable fluctuations. For instance, there was a temporary recovery of spending in 1990-92.
- The country report reproduced in Annex I emphasises that two sources of energy R&D spending are not covered in this review. First, state-level expenditure, much of it in California and most of it probably for demonstration purposes; the sum involved is uncertain (within the wide range of US$65-670 million). Second, energy R&D spending by the automotive sector (exceeding US$980 million in 1999). Footnote 1 of the country report provides details.
- The section on sectoral expenditure below shows that the 1990s saw a massive drop in private sector fossil fuel RD&D spending, while spending on renewable energy RD&D more than halved, and there were some cuts in the (small) nuclear RD&D component.
- After the private sector's reduction of US$1.7 billion in spending on fossil fuel RD&D, the next biggest component was a US$820 million reduction in public sector spending on nuclear RD&D. Public sector spending on fossil fuel RD&D fell particularly after 1992. There have been increases in spending on

‘Other Energy R&D’ (which, as noted in Chapter 1, the PCAST described as mostly “not very closely linked to advances in civilian energy technology or not really R&D at all”) and on energy conservation. Public sector expenditure on renewable energy has fluctuated (with weak years in 1988-90, and strong years in 1994-96).

- It has been suggested that deregulation of the electricity supply industry was the main reason for the reduction in private sector energy RD&D in the USA in recent years, but that analysis needs to take account of a switch away from generic, longer term investment to shorter term, more customer-oriented RD&D spending. (In the Sweden section below, it is suggested that while electricity supply sector energy RD&D has so far shown no sign of reduction in spite of deregulation, a similar switch to more customer-oriented spending has been taking place).
- The US Administration’s 2002 federal budget proposal is for heavy cuts in many research programmes (for example, an 8% reduction in the biological and environmental science programmes of the Department of Energy, and a cut of over 20% in the research programmes of the Environmental Protection Agency). There have been claims that existing programmes were not sufficiently effective, and new programmes will be proposed for 2003 onwards.
- In parallel with federal budget cuts there has recently been an impressive inflow of venture capital and a broader opening of financial markets to energy-related RD&D processes. The substantial investments of venture capital firms in what they call “power technologies” companies such as Capstone (microturbines), Plug Power and Ballard (fuel cells) are some examples of this.

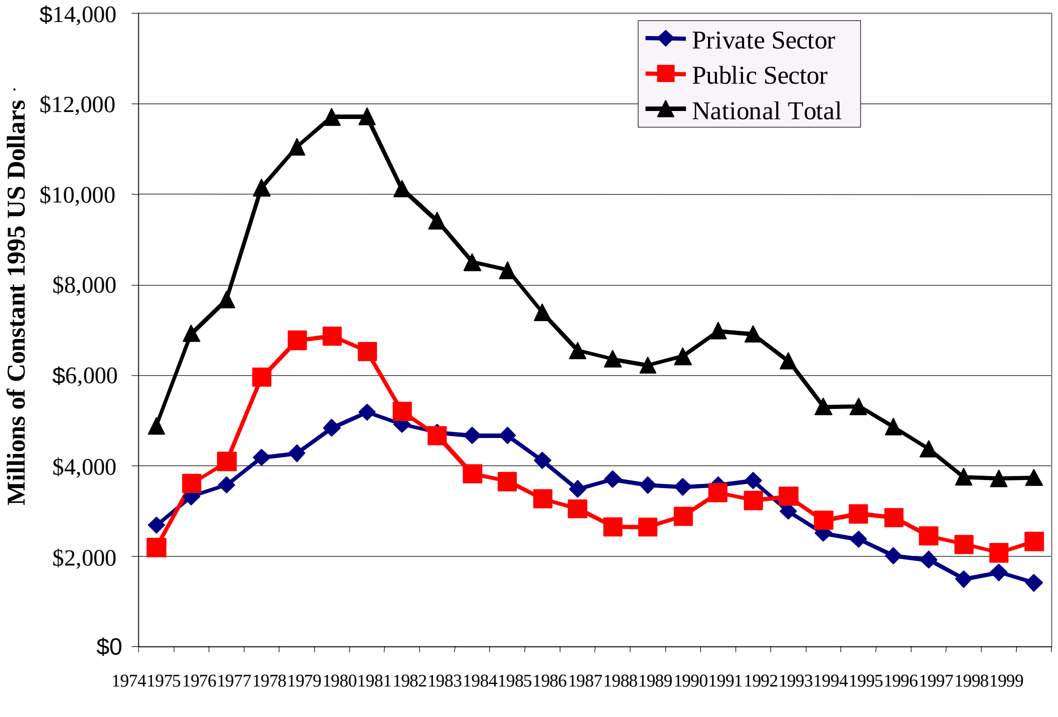

Chart 1. US national investments in energy R&D, 1974-99.

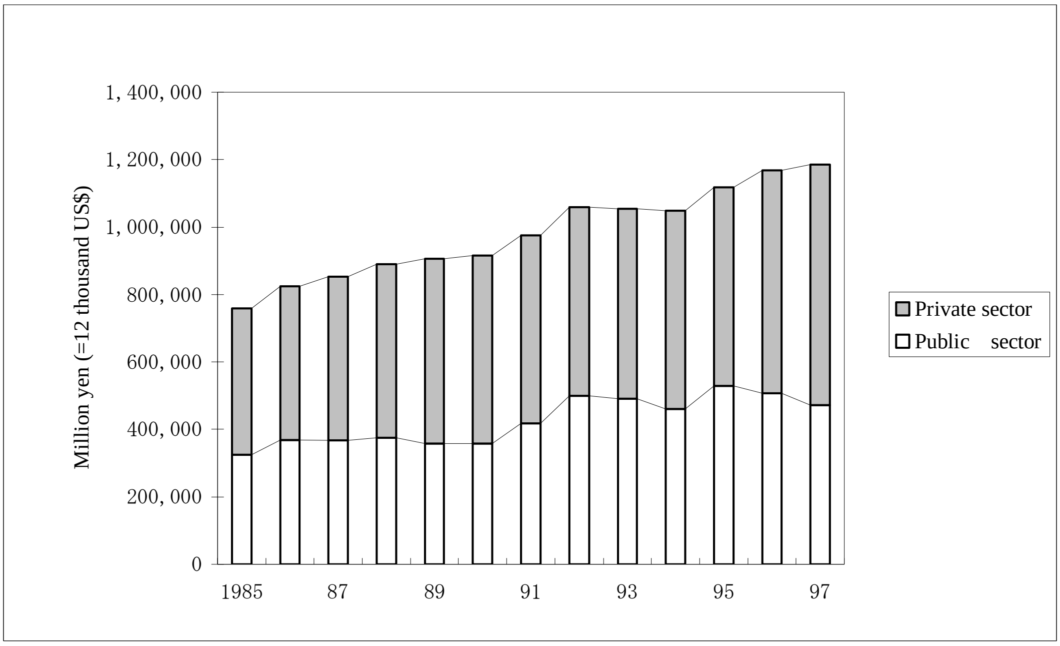

Chart 2. Japan's total R&D on energy, public and private sectors, 1985-97. (Source: Statistics Bureau, Management and Coordination Agency, Government of Japan.)

Japan

- The data in Annex I are shown in current Yen for the period 1985-97. Total energy RD&D expenditure increased steadily throughout this period, from almost ¥759 billion in 1985 to almost ¥1186 billion in 1997 (an increase of 56%). Chart 2 summarises this evolution.
- Total energy RD&D spending in both 1985 and 1997 was equivalent to 0.234% of GDP.
- Total private sector energy RD&D expenditure also increased steadily over the period, being over ¥434 billion in 1985 and just over ¥714 billion in 1997 (an increase of 64%). However, no separate information was available for the years 1992-95.
- Total public sector energy RD&D expenditure also rose steadily between 1985 and 1996, from nearly ¥325 billion to nearly ¥507 billion (an increase of 56%). However, presumably in part as a reflection of the Asian financial crisis that began in the middle of 1997, public sector spending fell by ¥35 billion in 1997 – to just under ¥472 billion. Thus the outcome for the whole 1985-97 period was an increase of 45%.
- Sectoral expenditures, as we shall see in more detail below, have held fairly steady or increased over the period.

Argentina

- No country report was received, but RD&D spending generally has been under pressure since early 1999. An article in *Nature* (30 November 2000) began: "Argentinean scientists, already facing financial constraints caused by the country's international debt crisis, are rebelling over the government's plan to reform the National Council for Science and Technology (CONICET)". No energy RD&D data were available.

Australia

- No country report was received. Australia's low level of RD&D expenditure has been criticised by many of its scientists in recent years (various reports in *Nature*), while others have questioned what seems to be hostility to the idea of human-induced global climate change which they consider has underpinned the energy-related research programme of the Australian Bureau of Agricultural Research & Economics (ABARE).
- The IEA's energy technology RD&D expenditure database for the Australian government's energy RD&D spending suggests a slowly rising level of effort between 1985 and 1995, but an upward surge in 1997 to A$160 million (see the section on IEA energy RD&D spending below).

Austria

- The government's total energy RD&D expenditure was provided for the whole period, but private sector expenditure only from 1993.
- Total energy RD&D expenditure was 0.014% of GDP in both 1998 and 1999.
- Government spending fell sharply from 1985 to 1987, which was attributed to the collapse of oil prices in 1985-86. In 1984 spending had been 462 million Austrian Schillings, but in 1987 it was only 256 million (national currency at current prices). After low spending levels in 1989 and 1990, expenditure tended to increase, especially after 1994. However, as will be seen in more detail below, spending on energy conservation has fallen slightly since 1994, whereas it rose until 1999 for renewable energy and cross-cutting items.
- Expenditures for private sector energy RD&D projects, which are co-financed by public means, fluctuated quite markedly from year to year between 1993 and 1998, with peaks in 1994 and 1998. These peaks corresponded with peaks in spending on energy conservation and renewable energy. Power and storage technologies also benefited in 1993 and 1994, but spending has fallen since.
- Spending on energy RD&D by the nationalised industry sector has fallen somewhat, and spending on renewable energy has fallen to well below the 1993 level. However, account should be taken of the fact that major parts of the nationalised industry were privatised in 1995.

Denmark

- Total energy RD&D spending probably rose from 1985 to 1993, then fell in the following three years before renewing its rising trend through 2000. The lack of certainty is mainly due to the absence of a full private sector time series, although there may also be an element of double-counting.
- Total energy RD&D expenditure in 1999 was 0.08% of Denmark's GDP.
- Danish government energy RD&D expenditure in 1998 constant prices was below 90 million Danish Kroner in 1985, exceeded 300 million in 1992 and 1993, and returned above the 300 million level from 1998. Increases were anticipated for 2000 and 2001, but the rate of increase is slowing close to the point of stagnation. Chart 3 summarises the evolution from 1985 to 2000.
- Private sector energy RD&D expenditure figures have only been collected every second year since 1987. A breakdown of the figures is only available for 1995, 1996 and 1997. There appears to be reluctance by the renewable energy sector (Denmark has an especially strong wind power sector, which is of international significance) to provide data on competitive secrecy grounds, although some figures were provided for 1995, 1997 and 1998.

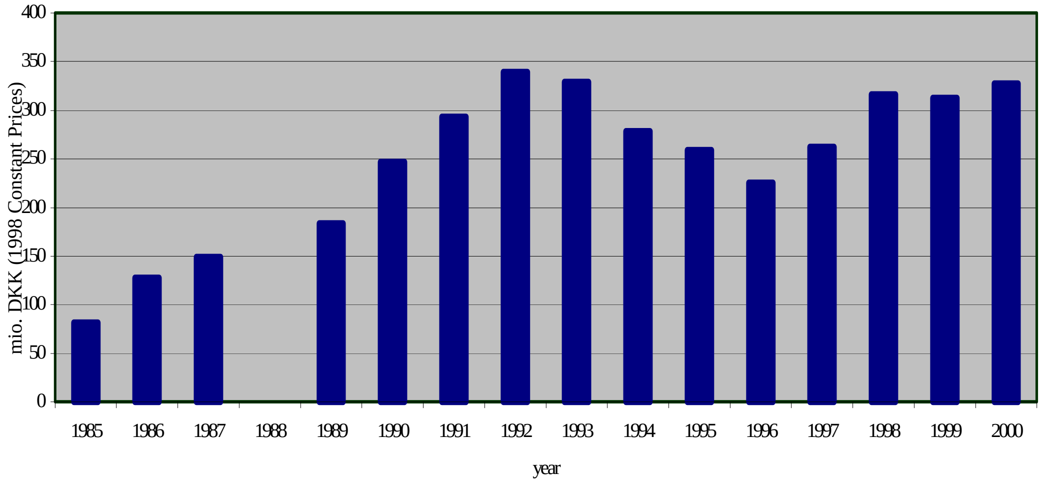

Chart 3. Danish public sector energy R&D funding, 1985-2000.

- There is concern that there may be a risk of double counting in aggregating private sector and government spending, as some of the former is funded by government research programmes. For that reason no attempt is made to sum the exact total of R&D expenditures in Denmark. However, the data provided suggest that private sector energy RD&D expenditure has been growing strongly overall. RD&D spending by electricity and gas utilities, however, has been falling since 1995 and 1997, respectively. This is attributed to the effects of restructuring and liberalisation in these sectors.

Finland

- Only public sector energy RD&D data were provided, from 1990. No private sector energy RD&D spending data were available.
- Public sector energy RD&D expenditure increased steadily between 1990 and 1998, from 193 billion Finnmarks to nearly 487 billion (an increase of over 250%) at current prices. Increases occurred across the board. In 1999 there was a 30% fall in overall public sector energy R&D spending, with the biggest single fall coming in R&D spending on conservation – down over 100 million Finnmarks (about US$15 million) or 40% – with significant falls in renewable energy, and also in power and storage technologies. Chart 4 summarises the evolution from 1990 to 1999.
- Public sector energy RD&D spending represented 0.065% of GDP in 1998, well up from 0.029% in 1990. Between 1994 and 1996 the share was between 0.041% and 0.048%, before rising to 0.065% in 1997 and 1998. In 1999, however, the figure fell to 0.044%, reflecting the fall in R&D spending previously mentioned.
- Private sector R&D in general increased steadily through the 1990s, but although figures are available for the chemical, metal and mechanical, food, electrical manufacturing, wood processing, and ‘other’ industries, no specific energy RD&D spending can be deduced. In recent years the electrical manufacturing sector has accounted for about 50% of the private sector RD&D total, but a significant proportion of this may be accounted for by mobile telephone and other communications equipment (Nokia spent over US$2 billion on RD&D in 1999).

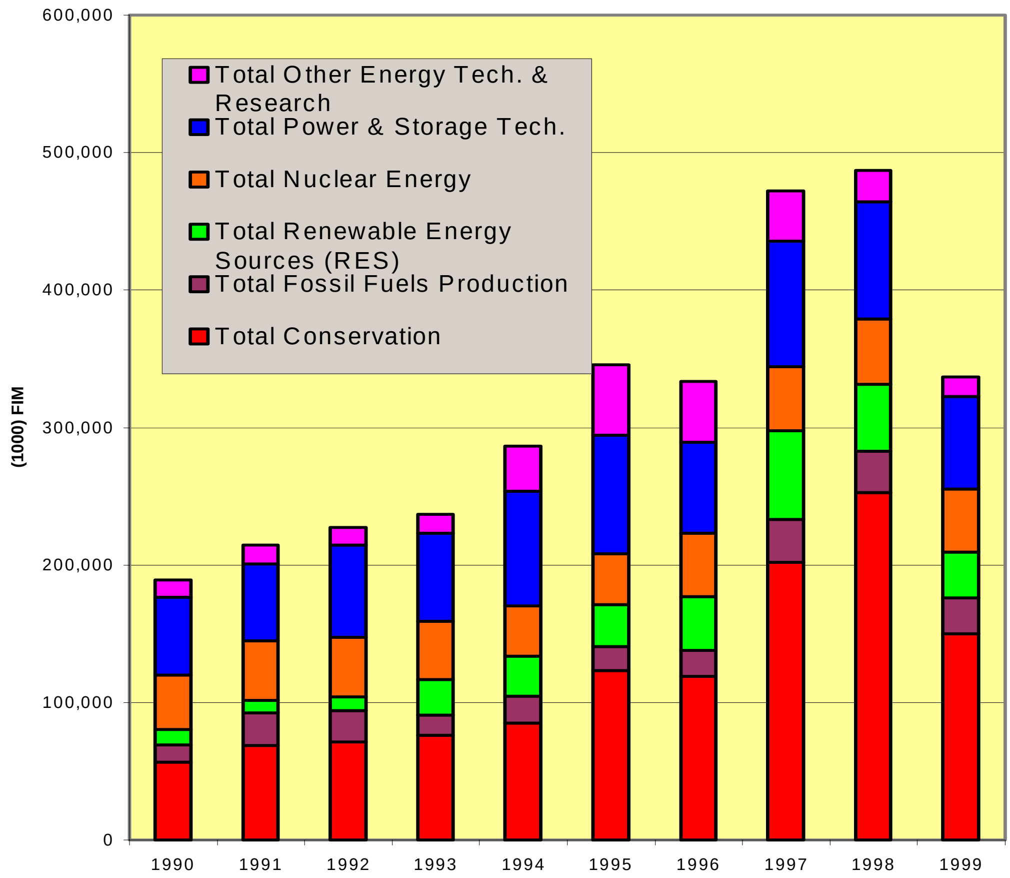

Chart 4. Total energy R&D expenditure in Finland, 1990-99 (public sector).

France

- Total energy RD&D expenditure by government fell sharply between 1985 and 1987 in constant 1999 local currency terms. Spending continued to fall more slowly until 1994, since when it has risen and reached a level in 1999 not seen since 1988. Chart 5 indicates the evolution 1990-98.
- No comprehensive private sector energy RD&D expenditure data were provided, but data were provided for electricity utilities, most oil and gas sector RD&D, and some institutional RD&D expenditures (Electricté de France (EDF), Framatome, CEA, Cogema, Alstom, Legrand and Schneider).
- Utilities are major contributors to overall RD&D spending on nuclear fission and fossil fuels, and are the major investors in RD&D on renewable energy, end-use technologies, and several other areas. EDF's RD&D spending steadily increased from 1990 to 1998, but fell over 10% in 1999. Framatome's RD&D budget fell somewhat in 1996-98, but rose strongly in 1999. Oil and gas sector RD&D spending fell slightly between 1993 and 1999 (spending by Total and Elf fell some 15% between 1996 and 1999).

Germany

- No country report was provided, but a federal government report on RD&D spending in general was provided which contains some energy RD&D data for the period 1994-98. This suggests that in this period expenditure on energy research and energy technology stagnated (in 1994 it was DM 871 million in current prices, and in 1998 it was DM 845 million).

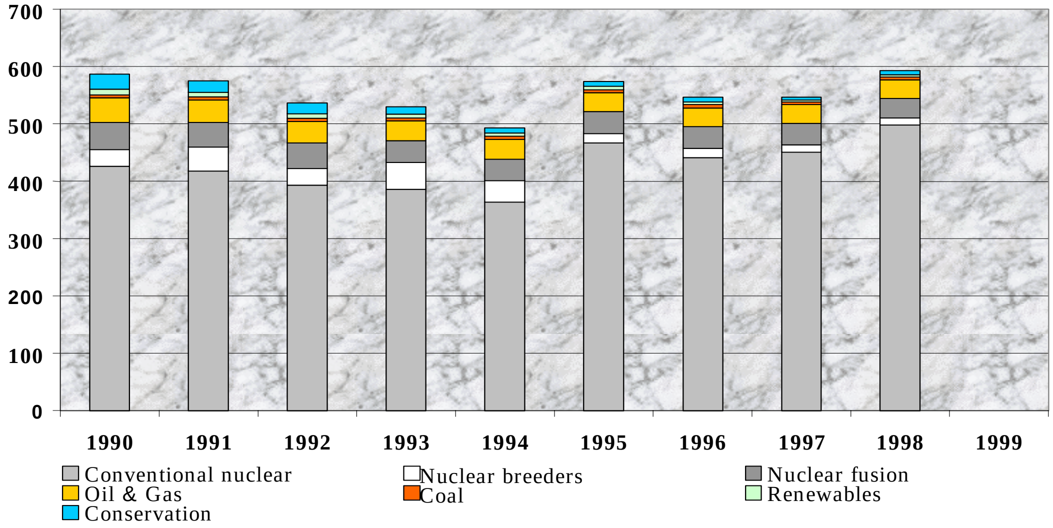

Chart 5. Evolution of government energy R&D budgets in France, 1990-98 (million US dollars – 1998 constant prices). (Source: IEA, 1999.)

- Federal spending on fossil fuels research has fallen quite sharply since 1994, while spending on renewable energy and conservation remained fairly steady through the 1990s (at levels significantly higher than in 1986 and 1987). Spending on nuclear fission RD&D collapsed after 1985, and has recently been running at about 10% of its former level. Spending on nuclear fusion has remained fairly steady, and now exceeds that on nuclear fission.
- The IEA data portray a sharper collapse in government spending on total energy RD&D at 1999 constant DM prices. From DM 2360 million in 1985, spending had fallen to DM 1016 million by 1989 (a fall of 57%), and since 1994 has been below DM 600 million.
- Unfortunately, no private sector energy RD&D spending figures were provided. However, Siemens reportedly spent over US$5 billion on RD&D in 1999 (Financial Times Survey, 15 September 2000).

Republic of Korea

- The full country report is reproduced in Annex I. It tells a rather remarkable story for the period 1985-97 (not least the fact that total energy RD&D expenditure more than doubled in 1995).
- Total energy R&D expenditure was 0.0545% of GDP in 1998, up from 0.0128% in 1985. Energy R&D spending rose 22-fold, while GDP rose 5.6-fold in this period.
- Total government energy RD&D expenditure in 1985 was less then 10.4 billion Won (at current prices); by 1990 it was over 24 billion; and in 1994 over 58 billion. In 1995 government energy RD&D expenditure rose to over 161 billion Won, and remained at this level in 1996 and 1997. But the Asian financial crisis intervened from July 1997, and so in 1998 government spending slipped back to 131 billion Won (a fall of over 20% in one year). It was not possible to get 1999 figures in time for this report.
- Chart 6 summarises the evolution of public and private sector energy RD&D spending in the Republic of Korea for the 1985-98 period.

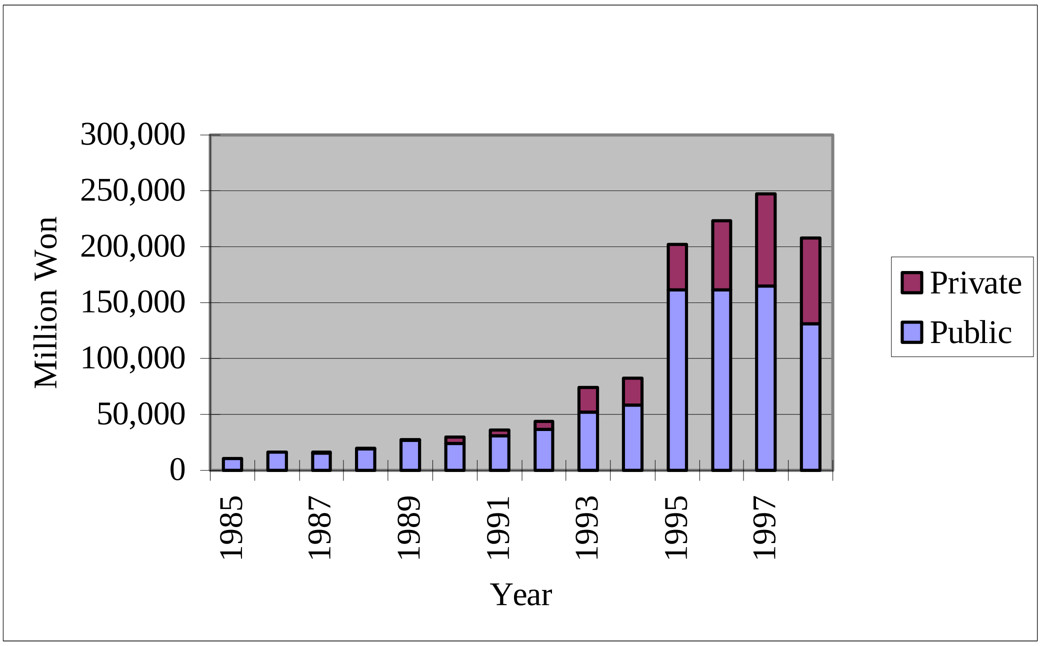

Chart 6. Total energy R&D expenditure in the Republic of Korea, 1985-98.

- Private sector energy RD&D spending in Korea also rose sharply from 1987 (the first figures available). In 1987 the private sector spent just 272 million Won; by 1990 over 5.1 billion; by 1995 over 40 billion. This latter figure doubled to nearly 82 billion Won in 1997 (all figures at current prices). In 1998 private sector spending fell just over 6% to 76.8 billion Won, principally because of the Asian financial crisis.

Mexico

- In the 1990s Mexico's public sector energy RD&D expenditure rose more than ten-fold. This was principally due to a rapid increase in energy RD&D spending by state-owned oil company Pemex after 1996. The Mexican Petroleum Research Institute also greatly increased its expenditure, 97% of which is dedicated to the oil sector and the remainder to gas. These two organisations accounted for 77% of Mexico's public sector energy RD&D spending in 1999.
- The remaining energy RD&D spending is accounted for by the Electric Research Institute, the Mexican Exploration Company, and the National Institute for Nuclear Research. The Electric Research Institute's R&D spending increased 40-fold (in current Mexican Pesos) between 1985 and 1999 (from just over 3 million Pesos to over 128 million – the peak figure was over 145 million in 1998). University research on energy in 1999 received a budget of 11 million Pesos, to fund programmes in the Energy and Engineering Faculty for solar energy and hydropower.
- A new President came to power in Mexico on 1 December 2000. As *Nature* reported on 9 November 2000: "Plans drawn up by him to bolster science and technology have received a cautious welcome from Mexican scientists. He has promised to double research and development spending as a proportion of Mexico's GDP, and to increase the number of scientists. Although they welcome his plans for science, many researchers are sceptical about how much will be delivered, given the current shortage of funding, the track record of past governments, and the lack of detail in the commitments. But the team's

coordinator of science and technology, Maria del Carmen Diaz, says big changes are planned. In addition to extra funding, the team promises to improve links between the academic world and industry…"

Pakistan

- Information was provided for a number of institutes. RD&D spending by the Hydrocarbon Development Institute fluctuated between 1985-86 and 1998-99 in a range from roughly 19 million Rupees (at current prices) to 25 million (except for a low in 1991-92 and a high in 1995-96). In 1999-2000 spending surged to nearly 33 million Rupees. Current expenditure has had a more stable evolution than development budget expenditure which, with the exception of 1995-96, fell away sharply after 1990-91. However, in 1999-2000 it increased again to reach its peak for the period.
- The Fuel Research Centre of the Pakistan Council for Scientific and Industrial Research (PCSIR), which focuses on indigenous fuels, has had a rising trend in RD&D spending, from under 2 million Rupees in 1985-86 to around 7 million Rupees since 1996-97.
- The National Institute of Silicon Technology, which focuses on solar energy and photovoltaic technology, had a sharp increase in its budget in 1985-86 (to almost 27 million Rupees). This fell back to just over 7 million the following year. Since then the Institute's budget has steadily increased, and in 1999-2000 it was 19 million Rupees.
- The budgets of the Pakistan Atomic Energy Commission were not available.

Poland

- Some data from Poland's Central Statistical Office for fossil fuel RD&D expenditure were provided for 1995-98. They show sharp rises in RD&D expenditure for coal (up over 50% in three years), oil and natural gas (up over 75% in three years), and electricity and gas supply (more than doubled in four years). Figures are based on Polish Zloty at current prices.

Saudi Arabia

- No figures on fossil fuel or nuclear energy RD&D spending were provided, but some US$15 million was spent on renewable energy and energy efficiency combined between 1985 and 2000.

South Africa

- Total non-nuclear energy RD&D expenditure rose between 1987 and 1989 from over 23 million Rand (at 1995 constant prices) to nearly 31 million. Spending in 1990 was below 25 million Rand. It rose again in 1991 to just over 29 million, but has fallen sharply since. In 1997 the figure was just under 5.5 million Rand (23% of the figure a decade earlier).

Spain

- IEA data for energy RD&D expenditure by government (local currency, constant 1999 terms) shows an uneven pattern between 1985 and 1999, with 1985 marking the start of a sharp fall. There was an expenditure peak in 1991. Although there has been a broad pattern of decline since 1991, in some recent years spending has been back close to the levels of the late 1980s.

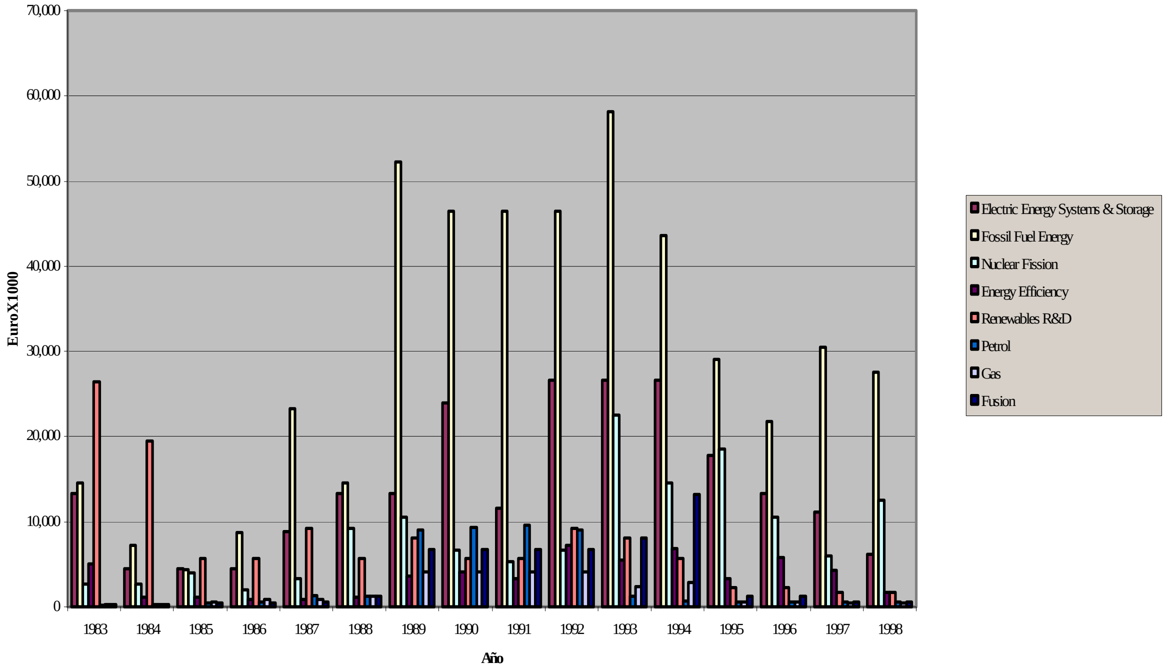

Chart 7. Spain's energy R&D expenditure, all sources, 1983-98.

- When account is taken of the electricity sector energy research programme in Spain, total energy R&D spending is considerably higher than government levels alone (it more than doubles the 1998 figure). Nevertheless, there remains a pattern of declining expenditure from 1993 under every heading – especially fossil fuel energy, renewable energy, electrical energy systems and storage, and uses of energy. The detailed figures are shown in Chart 7.

Sweden

- Sweden has had, and probably still has, one of the largest government energy RD&D programmes in the world on a per capita basis. Total government energy RD&D expenditure in Sweden rose sharply between 1975 and 1984, but since the oil price collapse at the end of the following year annual expenditure has fallen (in constant 1997 Swedish Kroner terms).
- The power industry's non-nuclear energy RD&D spending was on a rising trend in real terms from 1975 until 1993, but has since drifted downwards. Expenditure peaks in the early 1990s due to a few major demonstration projects (e.g. in biomass gasification for electricity generation) distort subsequent figures. Nuclear power RD&D expenditure has fallen since 1994, almost entirely due to lower government spending on nuclear fission RD&D. Chart 8 summarises the evolution of energy RD&D spending for 1975-97.
- The governmental RD&D programme gives greater emphasis to renewable energy applications (biomass and wind power particularly) and conservation than that of most other countries (measured as a share of the total programme).
- Important findings of the country report are that private sector spending has "changed its focus from previous 'core business fields' to more customer-oriented product development and new services", and that (while noting the imprecision of the data) "three years after deregulation the expenditures of the electricity supply industry have not decreased and may possibly even have increased somewhat compared to the levels of expenditure before the deregulation".

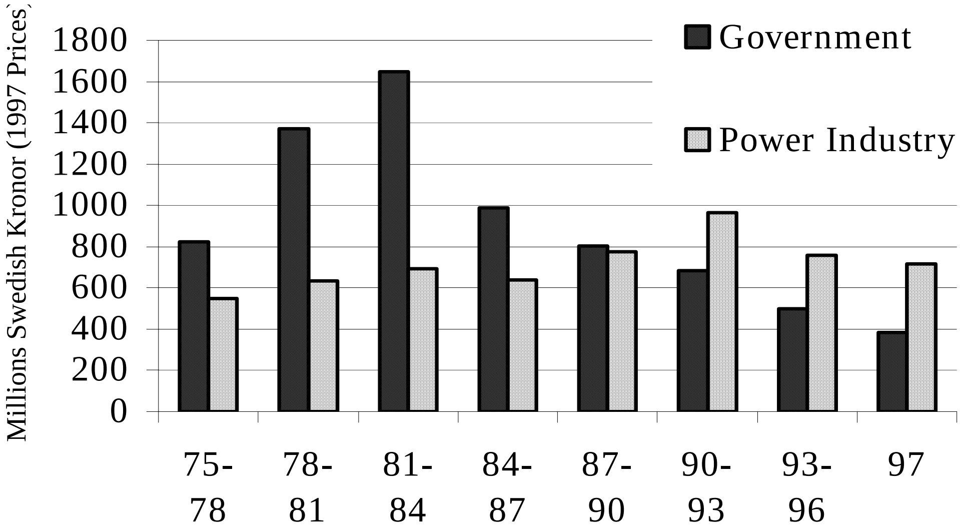

Chart 8. Sweden's annual energy RD&D expenditures, 1975-97 (government and power industry).

Switzerland

- Federal energy RD&D expenditure (in constant 1997 local currency terms) rose steadily from 1985 to 1991. It stagnated, but did not fall, between 1991 and 1994, but has fallen steadily since.
- Declines in nuclear power RD&D spending since 1990 and in energy efficiency RD&D spending since 1995 are the main reasons. There has been some offset from rising expenditure on renewable energy.
- Planned federal RD&D expenditure to 2003 suggests continuing declines in spending on nuclear fission and fusion RD&D, but stable or expanded expenditure on renewable energy, energy efficiency and technology transfer.
- Unfortunately it did not prove possible to obtain useful private sector energy RD&D expenditure. It has been reported that ABB spent over US$2 billion on RD&D in 1999 (how much of this was in Switzerland, and how much in Sweden, the USA and elsewhere was not known).

Swaziland

- A number of energy RD&D projects were notified to us, covering governmental, university and private sector activities. The budgets involved totalled less than US$250 000, dedicated to RD&D efforts in renewable energy projects. They covered solar, biogas and improved cooking stove projects.

2.1.2 European Union Energy Research & Technological Development

The share of energy in the European Union's Research and Technology Development (RTD) budget declined sharply in the 1980s, but remained stable in the 1990s. Chart 9 provides the details.

The EU's budget seeks to complement the often larger scale activities of member countries. It is oriented more towards longer term options (such as nuclear fusion) or doing things on a larger scale (such as renewable energy), which would normally be unattractive to the private sector.

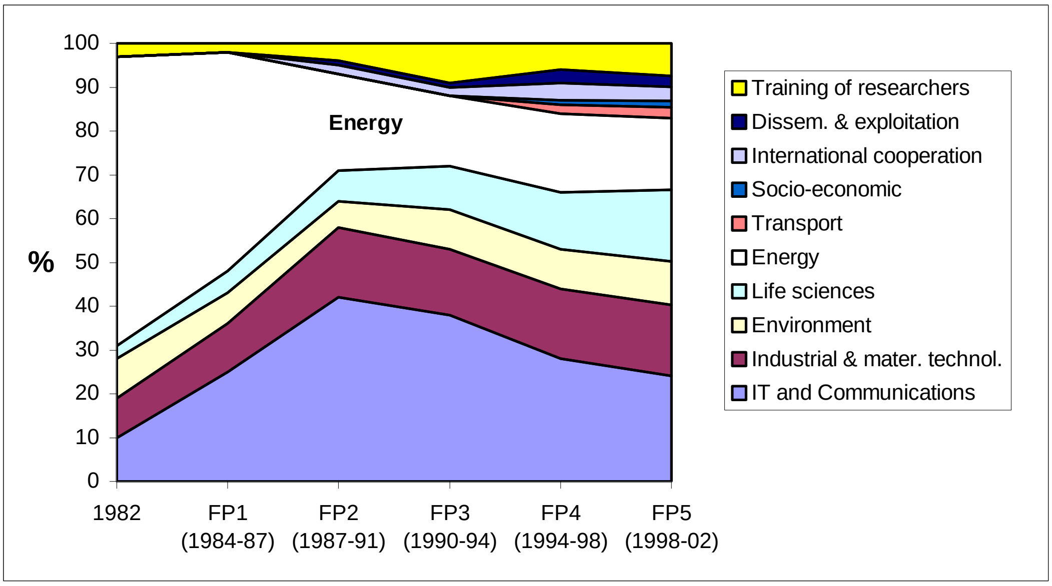

Chart 9. European Union research & technology development: changing priorities within the five framework programmes.

There have been five Framework Programmes, with a sixth proposed for 2002-06. The amount spent on nuclear research has remained fairly constant throughout (at around €1 billion per programme), although its share of the total RTD budget has fallen from 25% in the first Framework Programme to 9% in the fifth one. The non-nuclear element has fluctuated considerably – from €830 million in the first Framework Programme, down to €120 million in the second, up to €260 million in the third, and up to over €1 billion in each of the last two programmes. But if demonstration programmes are added in then the fluctuations are less marked.

The proposed sixth Framework Programme plans to allocate €700 million to nuclear fusion, €200 million to nuclear fission, and €850 million for non-nuclear energy research within the theme of "sustainable development and global change". However, these budget figures are at constant prices, and taking into account inflation and EU enlargement, represent a significant decrease in real terms.

2.1.3 IEA Government Energy Technology R&D Expenditure Data

The IEA's data series is considered here for those industrialised countries for which no country report or useful country data were received. Data are expressed in national currencies at 1999 prices.

Australia has already been referred to above. Data are available only for 1985, 1987, 1989, 1993, 1995 and 1997 (within the period 1985-99).

Belgium's total governmental energy RD&D expenditure fell sharply between 1985 and 1989 (by 55%), and was minimal between 1990 and 1994. Since 1994 it has been rising sharply, and in 1999 was back to the level of 1986.

Canada shows a steady fall in government spending on energy RD&D throughout the period 1985-99. Spending (in real terms) in 1999 was 37% of that in 1985.

Total governmental spending on energy RD&D in Greece fell sharply in 1989 and then declined steadily to 1995, when it began to recover. The latest figure available is for 1997, when spending had recovered to a level not seen since the late 1980s.

Figures for Hungarian government total spending on energy RD&D have been made available since 1994, but they fluctuate sharply – reflecting a decline in spending on renewable energy and an increase on nuclear energy (fission and fusion are not differentiated in the IEA data) and the category 'other'.

In Ireland, there were some modest outlays in the late 1980s (I£2–3 million maximum per annum), but there appears to have been no discernible energy RD&D expenditure by Irish government during the 1990s.

Italy is ranked in the top six government energy RD&D spenders among IEA member countries. It is regrettable that a country report was not obtained for this study, but a report for the Pacific Northwest National Laboratory is discussed in Section 2.1.4 below. The IEA data confirm a declining trend in energy RD&D spending by Italian governments between 1986 and 1989, which then became a rout. Spending halved between 1991 and 1993 and continued to decline through to 1998 (the latest year available). Spending in 1998 was 21% of the level in 1985, and 38% of the level in 1990.

Total energy RD&D expenditure by the government of the Netherlands fell after 1985 (the drop between 1985 and 1986 was over 26%), but then in most years to 1997 remained fairly stable. However, 1998 recorded the lowest level of expenditure in the period. There has not yet been evidence in these statistics of the increased energy RD&D budgets expected as a response to climate change and energy policy concerns (see Section 2.1.4 below).

Norway's governmental energy RD&D expenditure was on a rising trend between 1985 and 1992, but then fell steadily to 1998. In 1999 spending increased 26% on the previous year, back to the levels last seen in the early 1990s.

Total energy RD&D spending by the Portuguese government also fell back sharply from 1985 levels in 1986 (by over 30%), but then remained fairly stable until 1991, when there was a further sharp fall. Spending in 1994 was 42% of the 1991 level, and spending in 1995 more than halved again from the previous year. There was a slight recovery in spending in 1999, but only to a level which was 14% that of 1985, and 17% that of 1990.

In Turkey, total government energy RD&D spending rose substantially between 1985 and 1988-89, but then collapsed in 1990. There was some recovery in the following three years before further collapse in 1994. Spending more than doubled the following year and has since remained buoyant, with a spike in 1997 well in excess of anything previously experienced (due to a surge in spending on 'other oil and gas', and on coal).

In the United Kingdom, total energy RD&D spending by government fell at an increasing pace between 1985 and 1992, and then collapsed to scarcely 10% of the level of 1985. This collapse has been attributed to a major political/ideological shift to the belief that decisions on energy RD&D are now largely the concern of the private sector. This was reflected in the privatisation of the electricity and gas sectors, and the abolition of the UK's Department of Energy in 1992 (see Section 2.1.4 below).

2.1.4 Publications of the Pacific Northwest National Laboratory

There have been a number of relevant country studies, together with one on European Union programmes, published by the Pacific Northwest National

Laboratory (PNNL) in the USA. They broadly confirm the trends which have already been summarised:

- Government and private sector total energy spending has declined heavily in recent years in the USA. The peak year was 1980. Spending on nuclear RD&D since 1996 has been little more than 10% of the level of the early 1980s; spending on fossil fuel RD&D has tended to decline and be switched to more fundamental research; and renewable energy and energy efficiency have been the only consistent areas of growth in the federal energy RD&D budget. The downturn in private sector energy RD&D is attributed to lower energy prices and deregulation of the electricity and natural gas utility sectors.[1]
- Despite economic difficulties in the 1990s, Japan has maintained a relatively high level of energy RD&D expenditure, and gives it a higher significance than any other industrialised country. The emphasis on nuclear RD&D remains high, but has been in decline since 1996. Dooley reports that renewable energy accounts for only 3% of government RD&D support, and energy efficiency for only 8%.[2]
- Canada's government funding of energy RD&D has been in decline for many years (falling 18% between 1995 and 1999 alone), and aggregate private sector RD&D funding has remained essentially flat in real terms since the early 1980s. However, within the private sector total there have been declines in fossil fuel RD&D spending (down 60% between 1983 and 1995), while there have been modest increases in spending on energy efficiency and fuel cell technology, and by electricity utilities.[3]
- In Germany, government RD&D expenditure in general fell during the 1990s, but energy was the hardest hit (a 75% drop in energy RD&D spending during the period 1981-97). Most (90%) of this reduction was due to a fall in spending on nuclear fission. Government spending on fossil fuels RD&D was also cut by over 90%. Although renewable energy and energy efficiency fared relatively well compared to other energy technologies, all areas have declined in absolute terms since 1990. Both government and private sector energy RD&D spending now focuses increasingly on technology demonstration and commercialisation efforts with relatively short time horizons.[4]
- In the Netherlands, as already mentioned, government total energy RD&D fell in the period 1985-95, although the PNNL report anticipated a revival which had not occurred as of the end of 1998. Some recent increases have occurred in budgets for renewable energy technologies. About 40% of the government energy RD&D budget is accounted for by energy efficiency. Private sector spending, which accounted for 46% of the national total in 1995 (of which part is funded by foreign entities), is mostly devoted to energy efficiency. The private sector is the main investor in power storage technologies.[5]
- In Italy, total government energy RD&D expenditure declined significantly from the mid 1980s. This was mainly due to cuts in funding of nuclear fission RD&D, following a decision in 1987 to cease nuclear power production. However, declines also occurred in nuclear fusion, fossil fuels, renewable energy, and energy efficiency. Only spending on the category of 'other' general energy research increased during the 1990s. Up to the end of 1998 there was no evidence of an increase in expenditure on renewable energy and energy efficiency that the PNNL report states the government has called for. Italian corporate energy RD&D spending, most of which related to fossil fuels and energy efficiency, has also declined in recent years. Many of the

corporations involved were privatised during the 1990s, following which their RD&D expenditures declined significantly. The PNNL report, however, states that it is not yet clear what long-term impacts these privatisations will have on private sector energy RD&D expenditure.[6]

- As previously noted, total energy RD&D expenditure in the UK has declined sharply since the mid 1980s. Government spending fell 90% between 1987 and 1999. Private sector spending fell 55% in the oil and coal sectors, and 40% in the gas and electricity sectors. Renewable energy RD&D investment gained some benefit in the 1990s from the Non-Fossil Fuel Obligation placed on utilities by the government, which was then operative.[7]
- The report obtained on the European Union's energy research, discussed in Section 2.1.1 above (and reproduced in Annex I), shows that energy has a major – but declining – share of the EU's research budget. In the first Framework Programme (1984-87) energy accounted for over 50% of the budget, but it accounts for only 14% of the budget for the fifth Framework Programme (1998-2002). Nuclear fission RD&D has been the hardest hit (cut by over 50% between 1988 and 1998). Energy efficiency and renewable energy programmes have fared best, more than doubling since 1993 to become the biggest element in the energy RD&D component. However, the non-nuclear energy component has moved away from basic research towards an emphasis on technology commercialisation and economic competitiveness – especially with respect to energy efficiency and renewable energy.[8]

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2.2 Sectoral Energy RD&D Expenditure

In this section the report considers energy RD&D expenditures on the following sectors: the three fossil fuels; nuclear fission and fusion; renewable energy by category; efficiency/conservation; transport, conversion, transmission and distribution, and storage; energy systems analysis; hydrogen; and ‘other’. However, this is in effect a ‘wish list’, as in many cases the data available do not permit analysis in such fine detail. Further analytical categories are: basic research/applied research; development/commercialisation; and measures of the efficiency of RD&D expenditure (inputs/outputs). Data on the latter are extremely elusive, despite the frequency with which reference is made to their importance.

2.2.1 Fossil Fuels

The Study Group sought to receive information about RD&D on both conventional and advanced coal technology, on fuel cells under gas (with RD&D on hydrogen taken separately under renewable energy), on mining, and on carbon sequestration. Although there is information in the country report on Japan relating to electricity utilities’ RD&D on some advanced coal technologies and on hydrogen, and in the country report on the Republic of Korea relating to hydrogen, other information on these sub-categories was not obtained. Apart from what is contained in the country reports on Austria and Denmark, there is no separate information available on RD&D for enhanced oil and natural gas recovery. Given the potential importance of carbon sequestration, advanced coal gasification technologies, and hydrogen in providing the basis for modern and environmentally-friendly energy services in the future, this is regrettable.

In the USA, public sector fossil fuel RD&D expenditure fluctuated around a rising trend between 1985 and 1990, peaking at US$976 million (at 1995 constant prices) in 1990 (no disaggregated figures for coal, oil and natural gas were supplied). Expenditure then fell steadily and sharply, to US$236 million in 1999 (50% of the 1985 figure, and 24% of the 1990 figure). Public sector expenditure on fossil fuel RD&D represented 14% of total government energy RD&D spending in 1985, and 10% in 1999. Private sector fossil fuel RD&D spending in 1985 (at US$2.8 billion) represented 69% of total private sector energy RD&D expenditure. In 1999 this figure was about 74% (at some US$1.1 billion).

The breakdown of public sector energy R&D spending by fuel type is provided in Chart 10. It will be seen that nuclear fission and fusion R&D showed the biggest decline; fossil fuel R&D shows some decline, but there was a surge between 1990 and 1992; renewable energy and energy conservation R&D spending were relatively strong through the 1990s; and ‘other’ energy R&D spending declined somewhat.

In Japan, total fossil fuel RD&D expenditure fell from 1985 levels in 1987-89, but then rose gradually through to 1997 (the latest year available in the country report). Spending in 1997, at some ¥113 billion, was 34% above the 1985 level of ¥84.1 billion (current prices). These figures represented 11% and 9.5% of total energy RD&D spending in 1985 and 1997, respectively. They represented 9.7% and 9.1% of total public sector energy RD&D expenditure; and 12.1% and 9.8% of total private sector expenditure on energy RD&D, respectively.

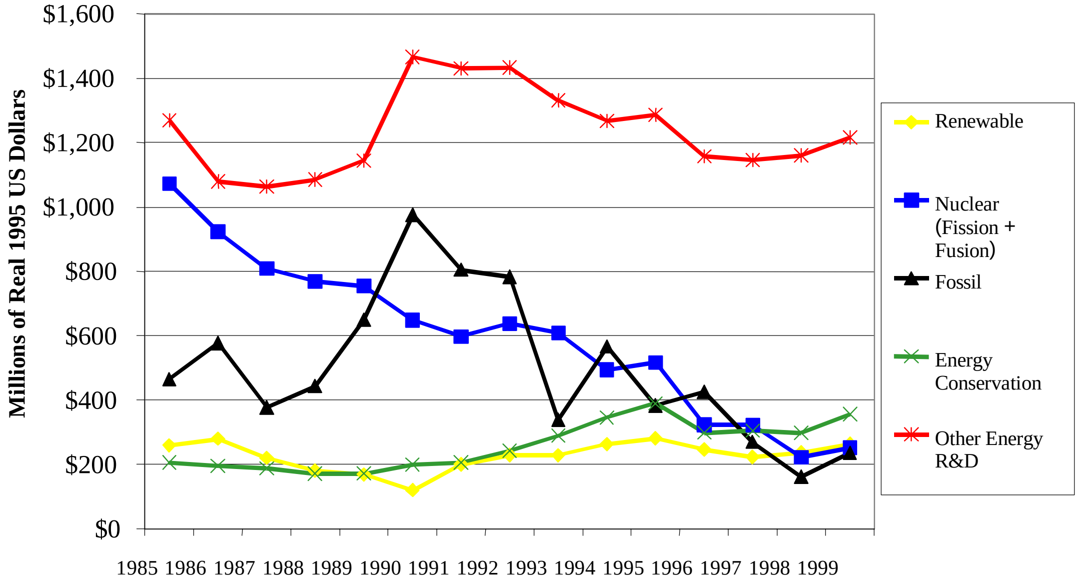

Chart 10. US public sector energy R&D investments by fuel type, 1985-99.

Total spending in Japan on coal RD&D in 1997 was almost ¥40 billion, the highest outlay in the period and 18% above the 1985 expenditure of ¥33.9 billion. Japan's electricity utilities' spending on coal RD&D saw a weakening in 1992-94 (from over ¥7.8 billion in 1990 to under ¥4.3 billion in 1994), but then some recovery to over ¥6.6 billion in 1999. Expenditure on oil RD&D was also weak in 1987 and 1988, but otherwise remained fairly stable during the 1985-97 period (¥40.7 billion in 1985 and ¥45.2 billion in 1997). Spending on RD&D in the gas sector began to increase from 1988, and rose quite sharply in 1996 and 1997. Whereas in 1985 RD&D expenditure on natural gas was only 11% of that on coal, and 9.5% of that on oil, by 1997 the proportions had risen to 56% and 49%, respectively.

The country report on Japan provides precise information on public and private sector fossil fuel RD&D spending, except for the years 1992-95. Public sector expenditure fell 23% in 1987 from the previous year's level, and did not start to recover until 1989. It seems to have remained stable at around ¥40 billion annually between 1991 and 1997. Private sector RD&D expenditure also exhibited weakness in 1987-89, but then recovered and by 1996-97 was around 33% up on the 1985 level. Public and private sector expenditure on coal RD&D broadly mirrors the aggregate fossil fuel RD&D spending pattern, whereas for oil public sector spending tended to rise over the 1985-97 period while private sector spending tended to fall. After 1985, public sector RD&D expenditure in the natural gas sector has remained fairly static at or below ¥1 billion per annum, whereas private sector RD&D on natural gas has risen five-fold since 1989.

In Austria spending on fossil fuel RD&D is so low and fluctuates so much from year to year that no clear trend is discernible.

Denmark has produced detailed figures on government fossil fuel RD&D spending for 1999 and estimates for 2000 and 2001. Total spending in this category has fallen since 1992, reflecting the reduction (and cessation after 1996) in coal RD&D expenditure, partially offset by the introduction of a programme of RD&D on enhanced oil and gas technologies in 1992, which continues at a level of around 12 billion Kroner per annum. Fossil fuel RD&D accounted for less than 6% of total government energy RD&D spending in 1999 – figures for 2000 and 2001 are expected to be lower still.

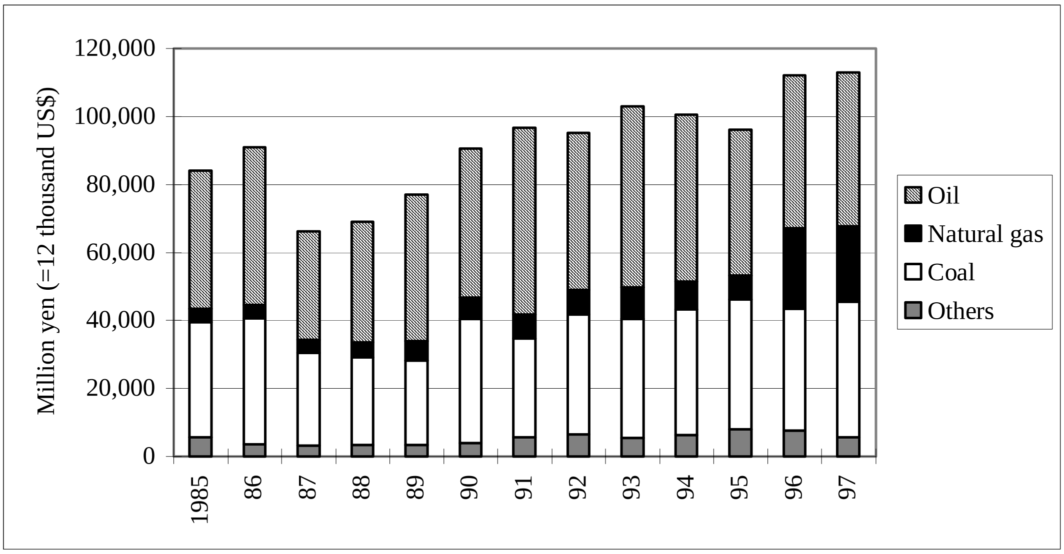

Chart 11. Japan's total R&D spending on fossil energy, 1985-97. (Source: Statistics Bureau, Management and Coordination Agency, Government of Japan.)

The country report on Finland provides government fossil fuel RD&D expenditure for 1990-99, showing lower outlays in the period 1993-96, but then a strong upturn in 1997 (due to a 12 million Finnmark investment in the oil refining, transportation and storage category). IEA data confirm this, and show a further 14 million Finnmark was invested by the government in the refining, transportation and storage category in 1998. The fossil fuels production RD&D expenditure category accounted for 13% of total government energy RD&D spending in 1990, and less than 7% in 1997. In 1999, however, there was a 13.5% fall in R&D spending on fossil fuels – though this was a much smaller drop than occurred that year in R&D spending on conservation, renewable energy sources, and power and storage technologies. Chart 12 sets out Finland's fossil fuels R&D expenditures to 1999.

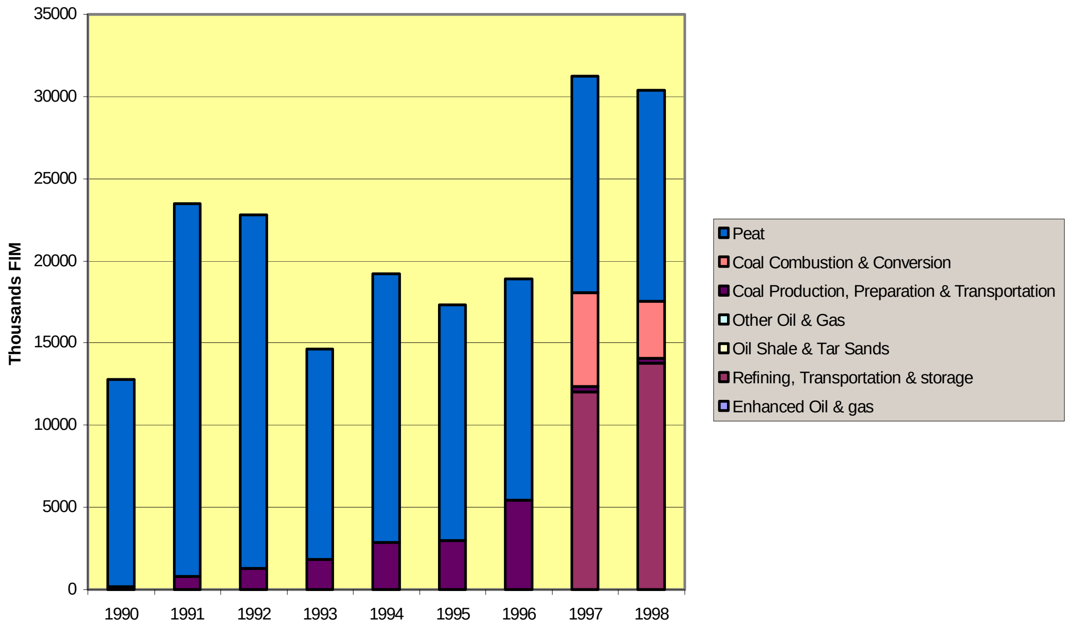

Chart 12. Fossil energy R&D expenditure in Finland, 1990-99.

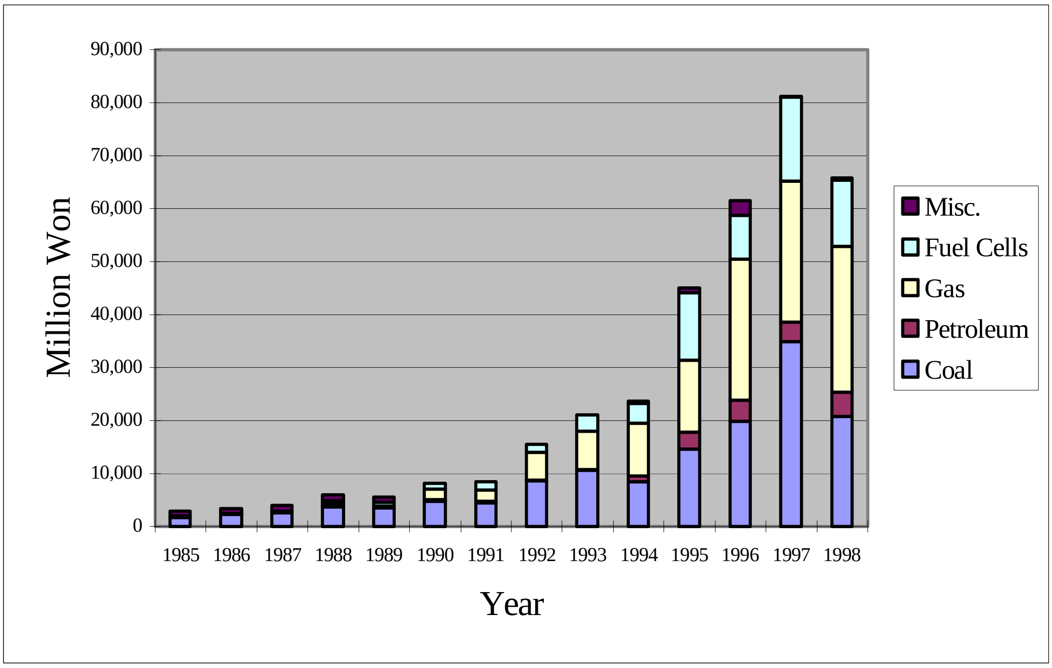

Chart 13. Total R&D expenditure on fossil fuels in Republic of Korea, 1985-98.

The country report on France quotes the IEA as the source for its chart on government energy RD&D expenditure, including fossil fuel RD&D. Coal RD&D expenditure ceased in 1997-98, while total oil and gas RD&D spending has declined steadily but slightly since 1985 (though buoyed up by expenditure in the enhanced oil and gas category from 1993 at a steady annual rate). In 1999 fossil fuel RD&D spending in real terms was 50% of its 1985 level.

Data provided on fossil fuel RD&D expenditure in Germany indicates that spending peaked in 1982. It then fell rapidly to 1995 and remains at a modest level. Expenditure in 1999 was less than 10% of the 1982 level, and 16% of the 1985 level. Expenditure in 2000 was estimated to have fallen nearly 20% below the 1999 level, to DM 32.9 million.

The country report on the Republic of Korea provides data on fuel cells and mining, as well as the three fossil fuels, for both the public and private sectors (Chart 13). Public sector RD&D spending on fossil fuels rose five-fold between 1992 and 1995, peaking at 30.3 billion Won in 1997. The fossil fuel component accounted for 28% of total government energy RD&D expenditure in 1985 and 16% in 1998. Spending on coal RD&D – the largest single category of expenditure for most of the 1985-98 period – remained fairly static until 1995, when it rose 2.5 times from the 1994 level. Spending on coal in 1997 was 65% higher than in 1995, at nearly 12.2 billion Won, but it fell back 26% in 1998. Remaining public sector fossil fuels RD&D spending is mainly on fuel cells, which gradually increased from 1985 and then rose four-fold between 1994 and 1995. Spending in 1997 was 43.5% higher than in 1995, and only fell back 21% in 1998 (to 11.5 billion Won).

Private sector energy RD&D spending in Korea was provided for 1987-98. For the first few years fossil fuels accounted for over 80% of the total, but in later years this share declined steadily and in 1998 was under 58%. Total spending increased sharply after 1989, rising four-fold between 1989 and 1990 and by a further four-fold between 1991 and 1993. Spending peaked in 1997 at 50.8 billion Won, falling to just over 44 billion in 1998. Coal and fuel cells are again the main components.

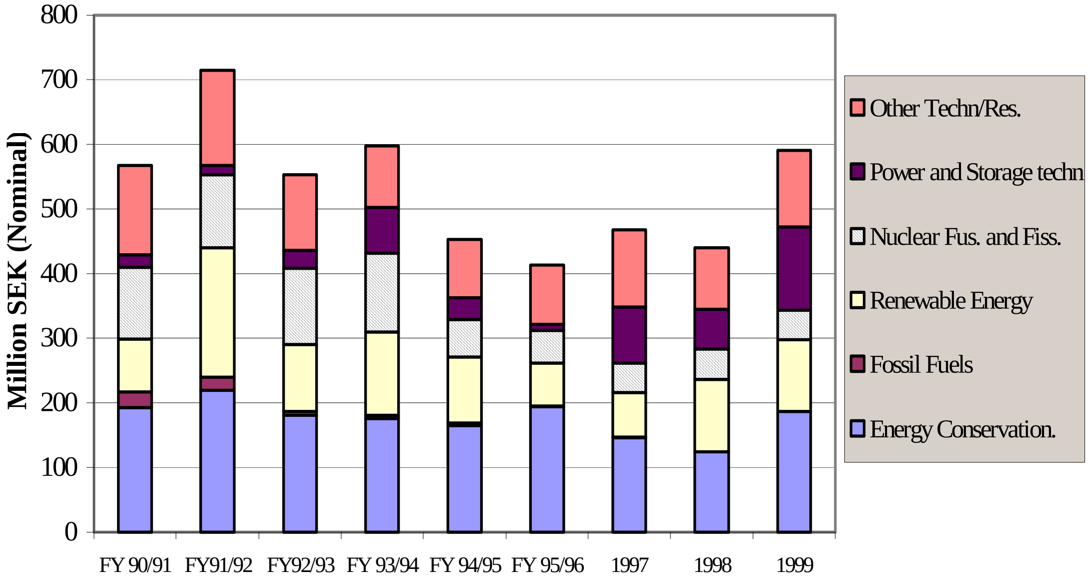

Chart 14. Energy R&D expenditure in Sweden (government appropriations), 1990-99.

In Spain, according to IEA data, government RD&D expenditure on fossil fuels (and on electrical energy systems and storage) in real 1999 terms fell sharply in 1984 and 1985, to 20% of total government energy RD&D spending in the latter year. Spending then rose, and maintained a level ten times that of 1985 in the period 1989-94, but has since been running at around half the previous annual level. The tables in Annex II show that, in current Pesetas, total spending on fossil fuel R&D has held up strongly, and in 1998 accounted for 37% of total energy R&D spending (over 60% more than was spent on renewable energy).

Government RD&D expenditure in Sweden on fossil fuels was phased out entirely by early 1997. Given the low dependence that Sweden has long had on coal, it is perhaps surprising that as late as 1985 coal RD&D spending accounted for 20% of total government energy RD&D expenditure. But spending on coal fell by nearly 60% in 1986, and by a further 60% in 1987, in real terms. Chart 14 provides a breakdown of Sweden's governmental spending on different fuels, which shows that fossil fuel expenditure can barely be discerned after fiscal year 1991-92.

IEA Data on Government R&D Spending on Fossil Fuels

In Australia, government fossil fuel RD&D expenditure has, by contrast with most countries considered, actually increased since 1985 in real terms. In Canada, such government spending has declined in real terms since 1986 – in 1999 it was less than 25% of the 1985 figure.

Government RD&D expenditure on fossil fuels in Italy ceased during 1989. In the Netherlands in 1998 such expenditure was 28% of its 1985 level; surprisingly, in all but two years in the 1985-99 period, fossil fuel RD&D spending (mostly on coal) was over half that spent in total on renewable energy. In Norway, less surprisingly, fossil fuel RD&D spending (virtually all of it in the oil and gas sectors) has been on a broadly rising trend, and in real terms was double its 1985 level in 1999. In Portugal, government fossil fuel RD&D spending has declined sharply in real terms since 1993.

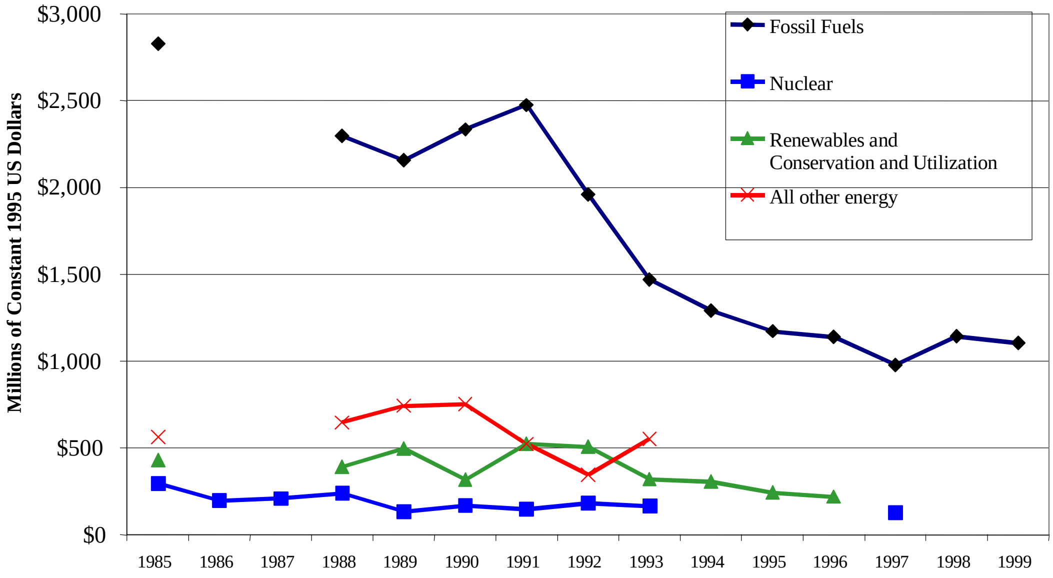

Chart 15. Estimated US private sector energy R&D investments by fuel type, 1985-99.

In Turkey, there was a surge in fossil fuel RD&D spending in 1997 – with spending on coal, oil and gas at record highs. In the UK, in keeping with the general decline remarked upon above, government fossil fuel RD&D fell sharply after 1988, but it has remained on a par with – or above – government spending on renewable energy RD&D.

2.2.2 Renewable Energy

In the USA, renewable energy RD&D expenditure has suffered a mixed evolution. Federal expenditure fell between 1987 and 1990, and then rose steadily (in real terms) to a peak in 1995 of US$280 million. It then fell again until 1999, when spending picked up once more to US$263 million (at 1995 constant prices). Expenditure in 1999 was close to the 1985 level.

US private sector spending on renewable energy RD&D is aggregated in the data with that on conservation and utilisation. The total for these three categories in 1985 was US$429 million, but only US$221 million in 1996, a fall of 48%. Chart 15 shows how private sector energy R&D spending by fuel type evolved in the period 1985-99.

In Japan, total spending on renewable energy RD&D has fluctuated within a fairly narrow band, except for a period of low expenditure in 1988-90 by both the government and private sectors. Spending on solar energy increased considerably in the 1990s (more than doubling between 1990 and 1997), and there was some increase in wind energy RD&D expenditure.

Most other renewable energy sectors in Japan have remained fairly static or, as in the case of biomass, declined somewhat. Government and private sector RD&D spending patterns have been rather similar over the period. In 1997, total renewable energy RD&D expenditure was almost ¥46.7 billion. Chart 16 sets out the evolution of expenditure for 1985-97.

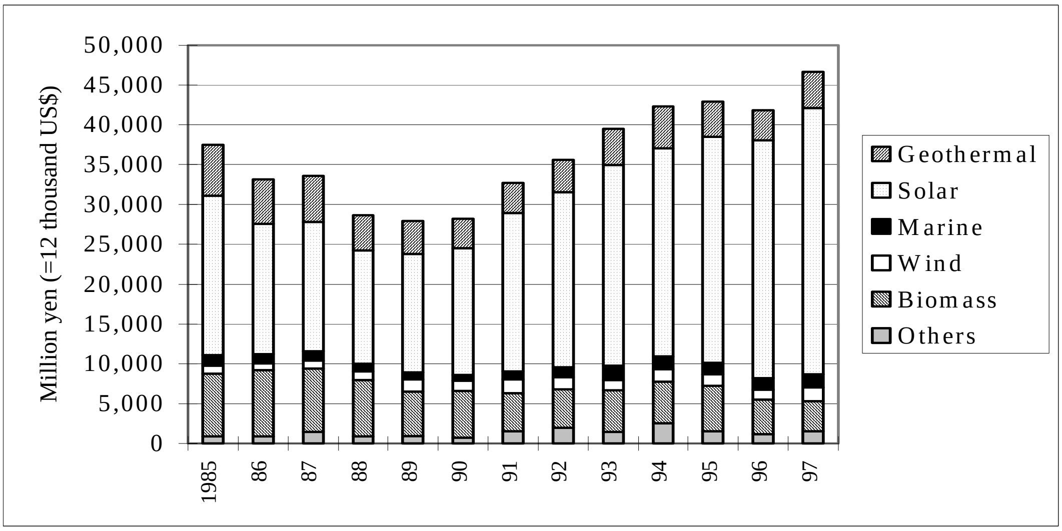

Chart 16. Total renewable energy R&D spending in Japan, 1985-1997. (Source: Statistics Bureau, Management and Coordination Agency, Government of Japan.)

Between 1993 and 1998, government spending on renewable energy RD&D in Austria doubled (to 135 million Schillings), but it fell nearly 6% in 1999. Biomass RD&D accounted for 65% of renewable energy RD&D spending in 1993, and 73% in 1999. Solar energy is the next largest category, and accounted for 32% of the renewable energy total in 1993 and 36% in 1998. However, spending on solar halved in 1999, and accounted for only 20% of the government renewable energy RD&D budget in that year. Expenditure on wind energy RD&D has increased markedly from 1993, but in 1998 still accounted for only 6% of the total, and it fell by 40% in 1999.

Within the solar energy category, expenditure had been fairly evenly divided between the photoelectric and the heating and cooling categories until 1999, when spending on heating and cooling collapsed to only 41.5% of the previous year's level and spending on photoelectric fell to 60% of the 1998 level. Geothermal RD&D expenditure also rose quite sharply until 1998, but then fell close to zero in 1999. Industry spending on renewable energy RD&D ran at 31–37% of the government level between 1993 and 1998, and rose nearly 70% over the period. However, this effort has been overwhelmingly (80% plus) concentrated on biomass throughout the period.

Not surprisingly, wind energy was the largest single component in the Danish government’s renewable energy RD&D spending in most recent years (1993 and 1994 were the only exceptions, when biomass took up more of the budget, reflecting interest in straw burning). Since 1991 total annual government spending on renewable energy RD&D has been fairly steady in real terms (with the exception of lower spending in 1996), reaching 116 million Kroner in 1999.

Unfortunately, it only proved possible to obtain detailed private sector RD&D spending on renewable energy for 1995, 1997 and 1998. There was an 89% increase in spending by wind turbine manufacturers and others between 1995 and 1998. Total private sector renewable energy RD&D spending was 549 million Kroner in 1998 (4.7 times the government level, though there may be some double-counting involved). With these caveats, Danish private sector energy R&D expenditure for selected years 1987-98 is given in Chart 17, and largely reflects spending on windpower.

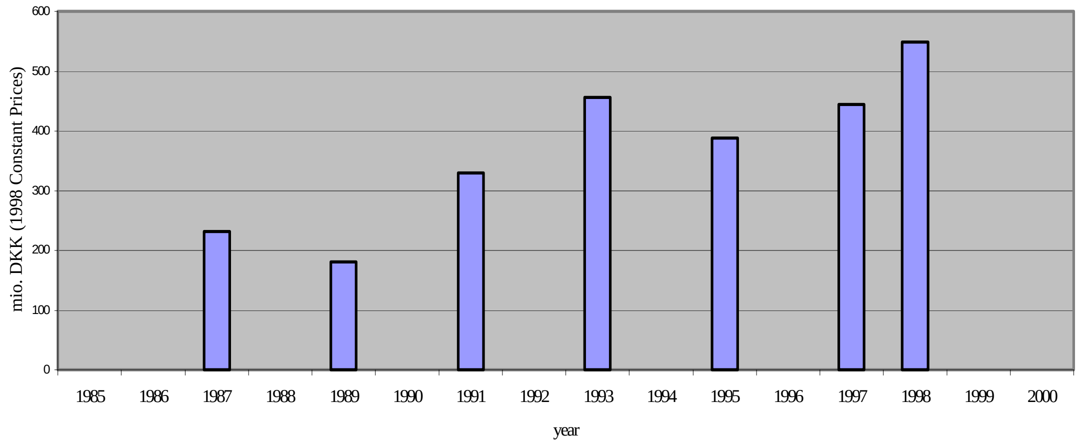

Chart 17. Danish private sector energy R&D expenditure, selected years 1987-98.

In Finland, government spending on renewable energy RD&D has mostly and increasingly been allocated to biomass. Total renewable energy RD&D spending increased nearly six-fold between 1990 and 1997 (to 64.5 million Finnmarks), and spending on biomass grew nearly 11-fold. In 1997, biomass accounted for 81.5% of the government's total spending on renewable energy. But in 1998 there was a 25% fall in spending on renewable energy, and a further 32% fall in 1999. Chart 18 shows government spending on renewable energy for the period 1990-99.

In France renewable energy RD&D by government remained at very low levels throughout the 1985-1999 period. However, it has risen from less than 4% of RD&D spending on total nuclear RD&D in 1985 to almost 17% in 1999. Two-thirds of recent renewable energy RD&D spending has been accounted for by solar (mainly solar photovoltaic) and biomass, in fairly equal proportions.

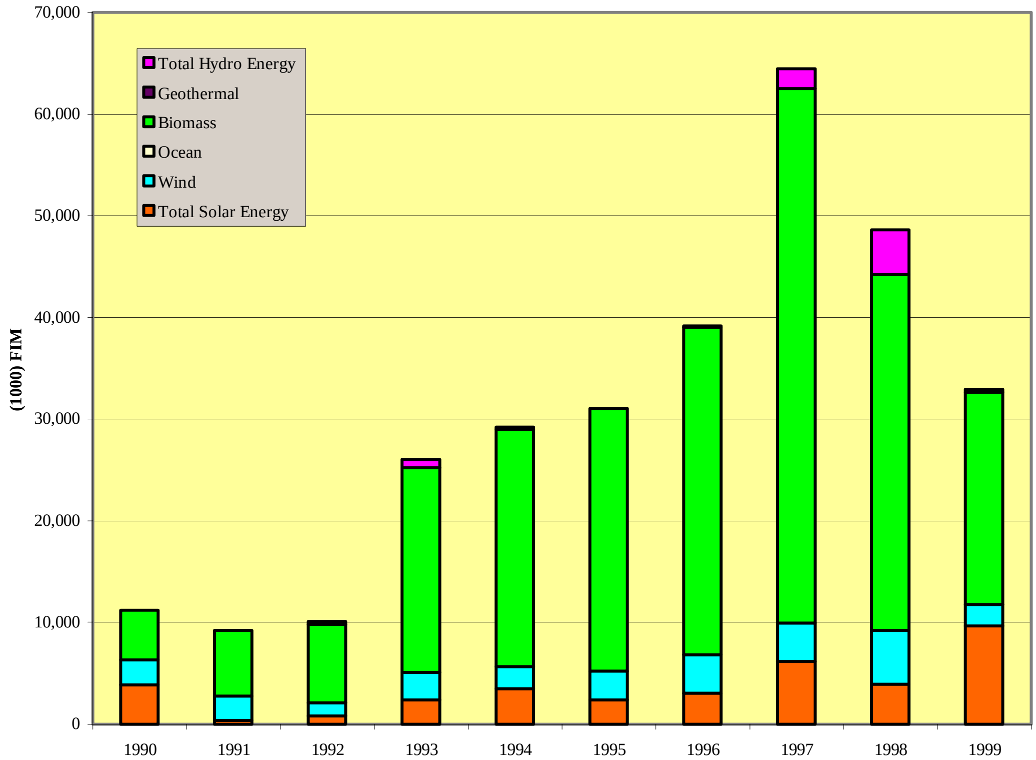

Chart 18. Government renewable energy R&D expenditure in Finland, 1990-99.

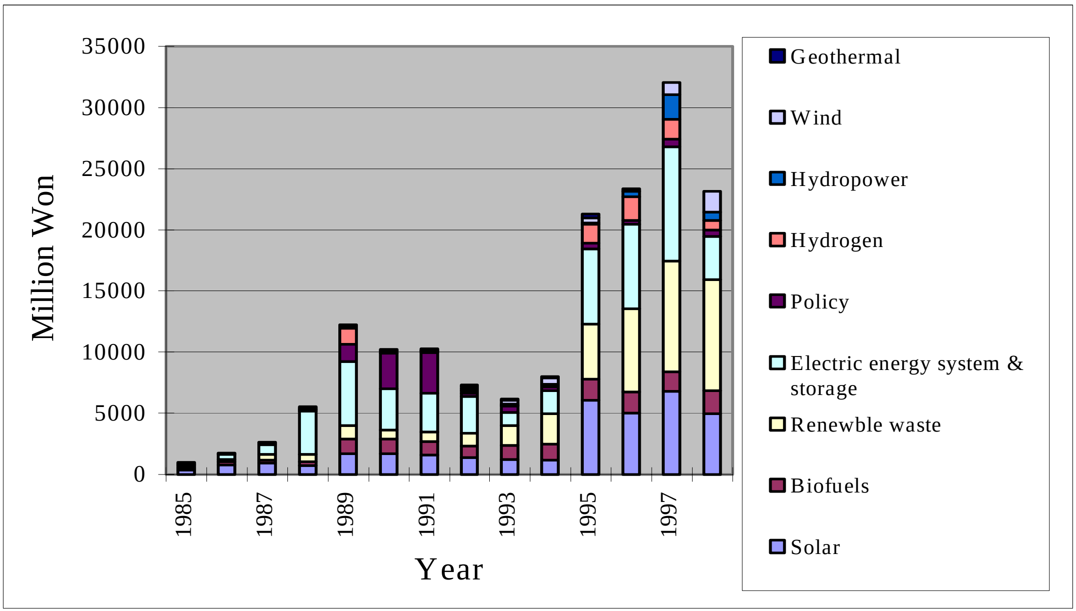

Chart 19. R&D spending on renewable energy in the Republic of Korea, 1985-98.

In Germany, while nuclear energy RD&D expenditure fell dramatically from the early 1980s, spending on renewable energy and energy efficiency RD&D (the two figures were amalgamated in the data provided) has remained more stable in nominal local currency terms – though at a consistently lower level than the 1992 peak. IEA data on government renewable energy RD&D expenditure (in 1999 constant prices) suggest that the peak spending year was 1993, and that at constant prices renewable energy RD&D spending in 1999 was only 54% of this peak. The reason for the change is that, while spending on wind energy RD&D rose and then stabilised from 1993, spending on solar energy fell back sharply. In 1999 it was only 53% of its 1993 level, and less than half its peak level two years earlier.

In the Republic of Korea, total public sector renewable energy RD&D spending rose over 12-fold between 1985 and 1989. Then a decline set in, reaching bottom in 1993 (at 48% of the 1989 level). Recovery came, especially in 1995, and in 1997 spending was almost four times the 1993 level. However, the Asian financial crisis helped cause a drop of nearly 40% in renewable energy spending between 1997 and 1998. The main thrust of expenditure has been on solar energy (photovoltaics and solar thermal), electrical energy, and policy and management. A significant amount was spent on hydrogen RD&D in 1995-97, but spending halved in 1998. In the private sector, renewable energy RD&D spending increased from 1992, and was heavily concentrated on renewable waste – spending was sustained at 1997 levels in 1998. Chart 19 provides total R&D expenditure on renewable energy in the Republic of Korea from 1985 to 1998.

In Spain, according to IEA data (in constant 1999 local currency), between 1985 and 1999 there was little change in government spending on renewable energy R&D (1999 spending was less than 10% below the 1985 level in real terms). The government provided major subsidies for the first commercial wind farms. The private electricity sector has spent only modest amounts on renewable energy in recent years (since 1995 the government has accounted for over 90% of R&D spending on renewable energy). Instead, the private sector has spent far larger sums on R&D on fossil fuels, nuclear fission, and electrical energy systems and storage, as the tables in Annex II indicate.

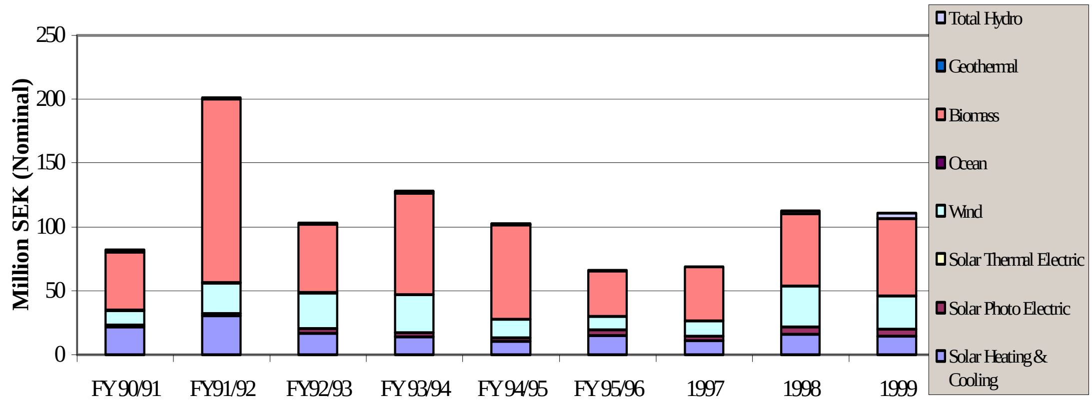

Chart 20. Expenditures on renewable energy RD&D in Sweden (government appropriations), 1990-99.

Although in Sweden total government spending on renewable energy RD&D fluctuated quite wildly during the 1990s, its share of total energy RD&D has been quite large by comparison with other countries. There was a big surge in 1992 due to a biomass project (which caused spending to more than double from 1991 levels, then halve again in 1993). In 1996 and 1997, spending fell to little more than 50% of the 1994 level, but there was recovery in 1998 and 1999 to levels not far short of 1994 (to almost 111 million Kroner in 1999). Biomass has taken up about 55% of the total renewable energy RD&D budget recently, with wind energy and then solar energy the next largest budget components. Chart 20 provides the evolution of government R&D spending on renewable energy sources in Sweden from 1990 to 1999.

IEA Data on Public Sector R&D Expenditure on Renewable Energy

Australia's governments over the period since 1985 have scarcely spent anything on renewable energy RD&D (by contrast to fossil fuel RD&D). Canada's governmental spending has also been modest by the same comparison (more than four times the amount is spent annually on fossil fuel RD&D than on renewable energy RD&D). Expenditure in Greece has varied considerably from year to year, but has not returned to the level of the late 1980s.

Italy's governmental spending on renewable energy RD&D has been large, although it has fallen somewhat in real terms since 1995. Most of the budget is allocated to solar photovoltaics and biomass, after a heavy wind energy programme in the early 1990s. In the Netherlands, a reduction in government expenditure on wind energy RD&D after 1985 pulled down total government renewable energy RD&D spending. Despite the country being at the leading edge of concern about global climate change, this has remained fairly static in real terms ever since.

Norway's governmental spending on renewable energy RD&D has also been modest (16.5% that of fossil fuel RD&D expenditure in 1999), most of it funnelled to large hydropower (over 10 MW). Portugal's governmental spending on renewable energy RD&D in real terms since 1992 has been a small fraction of earlier years (in 1999 it was 31% of the level of 1985). Spending on solar energy in 1999 was only 18% that of 1985, on wind energy 8%, and on biomass 8%; only RD&D on ocean energy has increased in recent years.

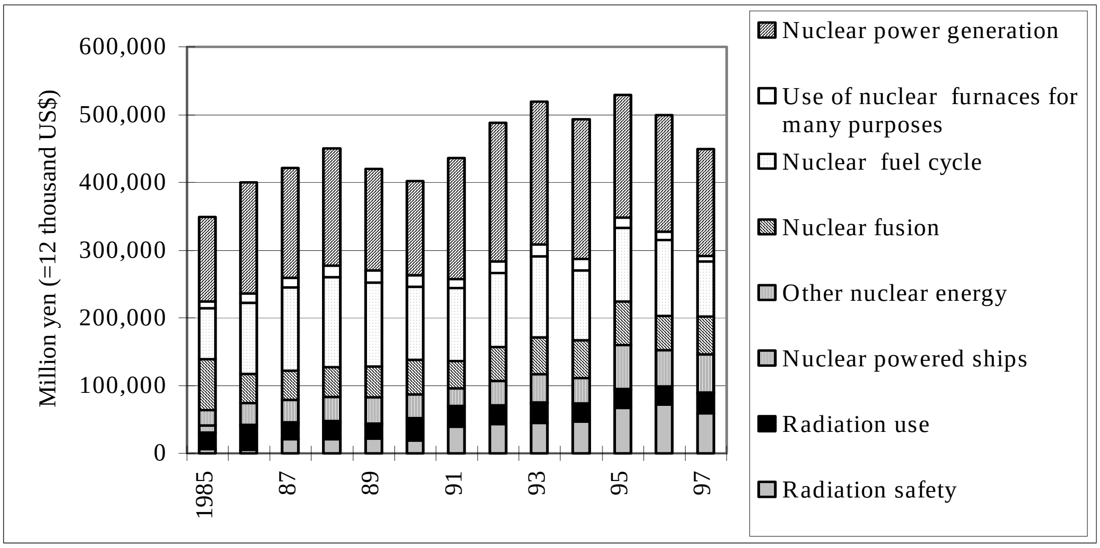

Chart 21. Japan's total R&D spending on nuclear energy, 1985-97. (Source: Statistics Bureau, Management and Coordination Agency, Government of Japan.)

RD&D expenditure on renewable energy by the Turkish government has fluctuated wildly from year to year, surging in 1997 and then falling away again. In the UK, governmental renewable energy RD&D collapsed across the board in the early 1990s and showed no signs of recovery through 1999.

2.2.3 Nuclear Energy

The collapse of US federal spending on nuclear (fission plus fusion) RD&D from 1985 was spectacular, and the sums involved were huge. Whereas total federal energy RD&D spending fell by US$760 million between 1985 and 1998, nuclear energy RD&D spending alone fell by US$950 million, from US$1073 million to US$120 million (down 89%) – although there was a small increase in 1999. This comparison needs to be borne in mind when it is suggested that US federal spending on energy RD&D has undergone a comprehensive collapse since 1985.

The difference is made up by increases in spending on energy conservation (up US$92 million) and on 'other energy R&D' (up US$342 million). Chart 10 shows the collapse in US public sector nuclear R&D spending from the mid 1980s. Given the size of nuclear fission RD&D in total US federal energy RD&D spending (it was 33% in 1985, but in 1998 was less than 5%), and the size of US energy RD&D in the world and OECD totals (about 40% of the latter), this decline in nuclear RD&D is a major explanation for the decline widely perceived in total energy RD&D around the world. Some serious qualifications have to be placed on the suggestion that there has been a comprehensive collapse across all countries and energy sectors in energy RD&D spending – the true story needs to written with more consideration for country and sectoral specifics.

In Japan, for instance, total energy RD&D expenditure grew between 1985 and 1997; and total nuclear energy RD&D spending in 1997 was 29% higher than in 1985 (although it fell 15% between 1995 and 1997, perhaps influenced by two major domestic incidents in the industry in quick succession). Total expenditure on nuclear RD&D was nearly ¥349 billion in 1985, and nearly ¥450 billion in 1997.

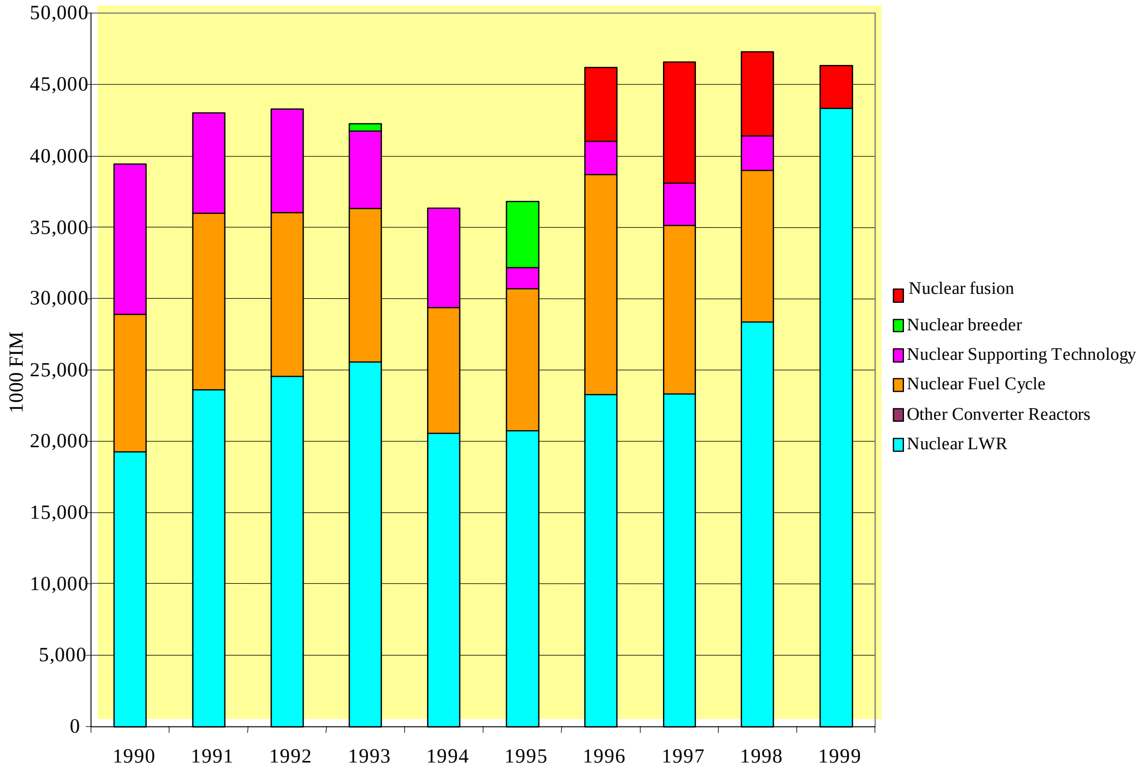

Chart 22. Nuclear energy R&D expenditure in Finland, 1990-99.

As the country report shows, RD&D expenditure on nuclear fusion has fallen recently, as has spending on the nuclear fuel cycle and nuclear power generation. Spending by electricity utilities on nuclear RD&D has also declined – from ¥77 billion in 1995, to just over ¥50 billion annually in 1999-2001. Chart 21 sets out the evolution of Japan's total R&D spending on nuclear energy for 1985-97.

There was a doubling in Austrian RD&D expenditure on nuclear fusion in 1998 (to 32.7 million Schillings), following an 82% increase in 1997. There was a further 8% rise in 1999. This reflects Austria's participation in the Euratom nuclear fusion programme, which led to substantially increased RD&D expenditure in this field by universities.

Denmark, despite its anti-nuclear stance, invested 33 million Kroner in nuclear supporting technology and nuclear fusion RD&D in 1999, and was expected to have increased that level slightly in 2000 and 2001.

In Finland, government spending on nuclear RD&D has been steady, with over half the budget going to LWR projects in recent years. The nuclear fuel cycle attracts about 25–33% of the nuclear RD&D budget. Spending on nuclear fusion rose steeply in 1996 and 1997. Total government RD&D spending on nuclear in 1997 was almost 46.6 million Finnmarks, and only fluctuated slightly in 1998 and 1999. Chart 22 sets out the evolution from 1990 to 1999.

In France, the nuclear sector accounts for over 90% of government-financed energy RD&D. Nuclear fission accounts for nearly 87%, and nuclear fusion for nearly 6%. In 1998, spending on nuclear RD&D totalled about US$550 million. By comparison, renewable energy accounts for 0.7% of energy RD&D spending. Nuclear energy RD&D accounts for 31% of total utilities' energy RD&D, whereas renewable energy accounts for 2.5%, transmission and distribution 17%, end-use technologies 21%, and 'other issues' 22%.

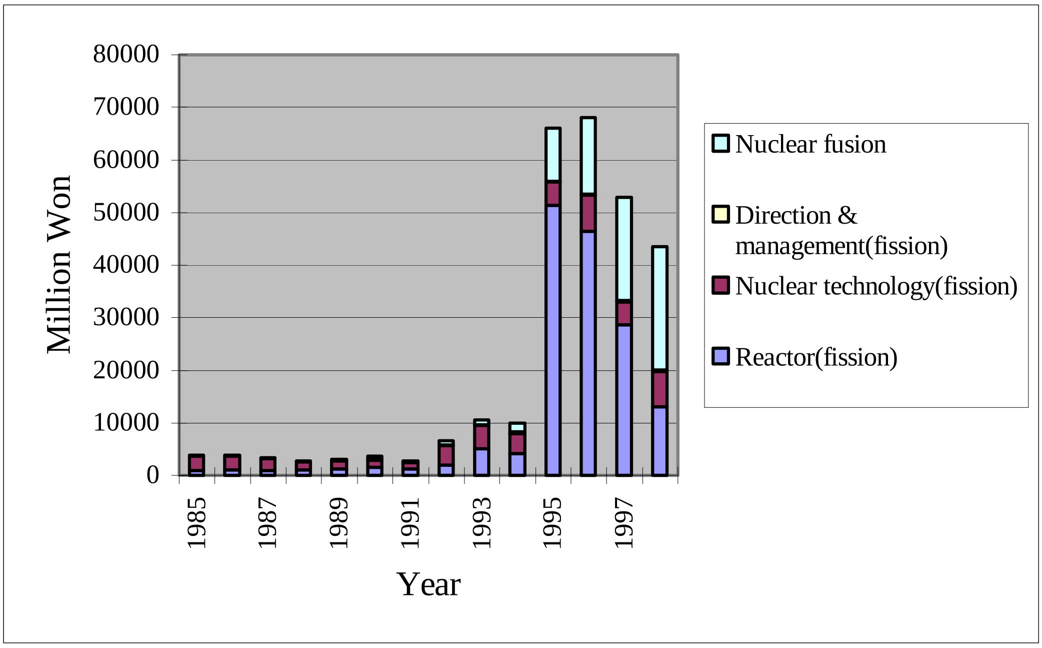

Chart 23. R&D expenditure on nuclear energy in the Republic of Korea, 1985-98.

Government nuclear energy RD&D expenditure in Germany in 1999 was only 10% of the 1985 level. Spending fell 30% in 1986, a further 30% in 1987, and has fallen steadily ever since.

In the Republic of Korea, government spending on nuclear fission RD&D took off in 1995 (up nearly seven-fold on the previous year), but fell sharply in 1997 and still further in 1998 (to 36% of the 1995 level). 1995 also saw an increase in Korea's nuclear fusion programme, which continued to expand through 1998 (overtaking the fission programme). Nuclear fission and fusion together took up 33% of the government's energy RD&D expenditure in 1998. Since 1992, Korea has also had a strong private sector nuclear fission technology RD&D programme. Chart 23 sets out the evolution of Korea's R&D expenditure on nuclear energy between 1985 and 1998.

As previously noted, Mexico has a small nuclear energy research programme, accounting for 6% of energy RD&D expenditure in 1999.

The Spanish government supported nuclear fission and fusion RD&D programmes throughout the 1980s and 1990s. Expenditure peaked in the early 1990s (in constant money terms) according to IEA data, and spending in 1997 and 1998 was only at 4.5% of the peak level. About two-thirds of the 1983-98 expenditure went on fission (two-thirds of which went on LWRs, with the rest on nuclear technology more generally), with the remainder spent on fusion. The private sector's nuclear energy R&D spending has been substantial since 1988, and in 1998 it was 75% greater than the government's.

In Sweden, government spending on nuclear fission and fusion RD&D continued through the period 1991-99, but has fallen by over 60% since 1994. There was a surge of spending on fusion in 1994, followed by an 80% reduction the following year, which explains most of the overall reduction. In 1999, government nuclear RD&D expenditure was some 45 million Kroner. Chart 24 sets out Swedish governmental appropriations for nuclear fission and fusion R&D for 1990-99.

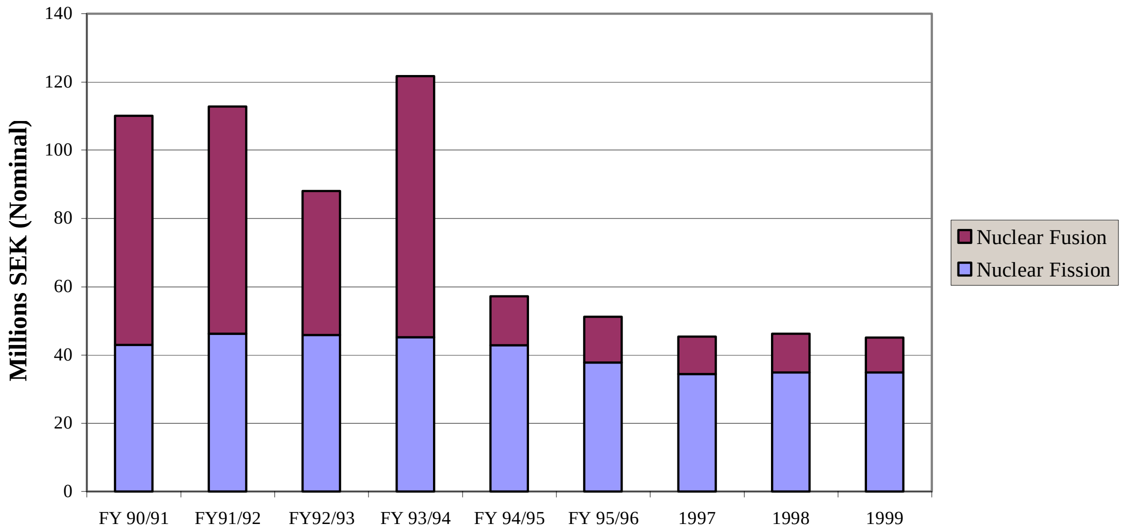

Chart 24. Government RD&D expenditure on nuclear fission and fusion in Sweden (government appropriations), 1990-99.

IEA Data on Government Nuclear Energy RD&D Expenditure

Data from the IEA for government expenditure on nuclear technology RD&D indicates that in Canada spending has been falling quite steadily since the mid 1980s. In 1999, spending was about 40% of the level in the mid 1980s. Greece has phased out its nuclear energy RD&D programme. Italy's nuclear energy RD&D budget in 1998 was only 10% that of 1985 (when the country had a major fast breeder programme). In the Netherlands, the nuclear energy RD&D budget has declined from its peak in 1992, and now stands at about 50% of the level in the late 1980s.

Norway’s nuclear fission RD&D programme has long exceeded its renewable energy RD&D programme, and is now about double the budget of the mid 1980s. Portugal began to phase out its nuclear energy RD&D programme in 1995, and this was completed in 1997. In Turkey, nuclear energy accounts for nearly 30% of the government’s energy RD&D budget. In the UK, nuclear power accounts for 33% of what little is left of government energy RD&D expenditure.

2.2.4 Energy Conservation/Efficiency

In the USA, although spending on energy conservation appears relatively modest within the total federal energy RD&D budget (though it is more than is spent on renewable energy), it rose by 73% in real terms between 1985 and 1999. However, the US Administration which came into office in January 2001 has indicated that increasing power generation from traditional energy sources is a higher priority than energy conservation (US Vice President Cheney, 30 April 2001). Private sector spending on conservation cannot be distinguished from that on utilisation and renewable energy, but a steady decline has been noted from 1992 to 1996.

In Japan, RD&D spending on energy conservation doubled between 1985 and 1997, to over ¥538 billion. In most years, 65–70% of total spending on conservation has gone to the transport field. Almost all of this expenditure is undertaken by the private sector.

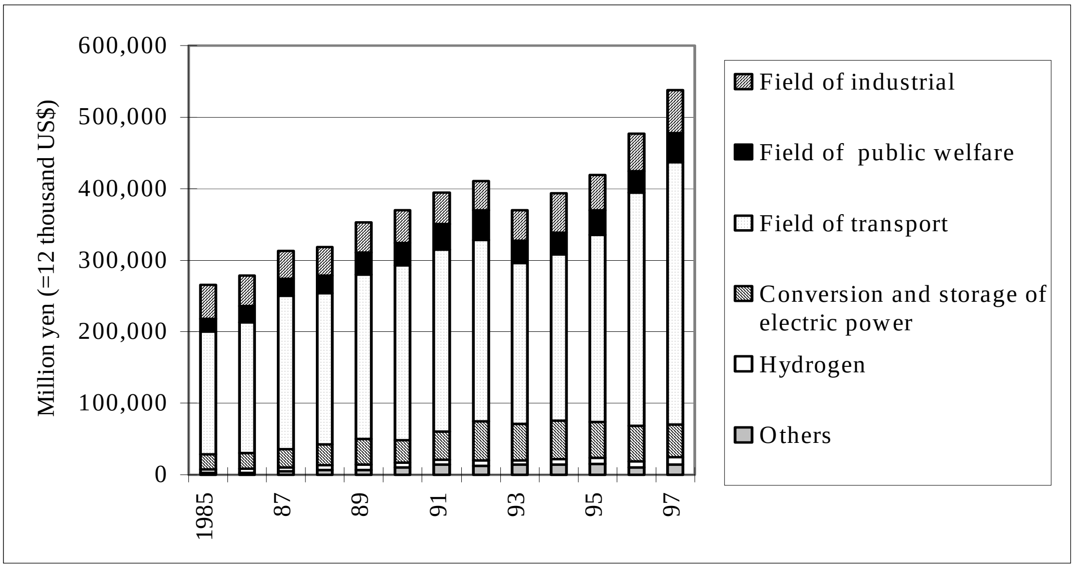

Chart 25. Total R&D expenditure on energy conservation in Japan, 1985-97. (Source: Statistics Bureau, Management and Coordination Agency, Government of Japan.)

Overall, energy conservation accounted for 45% of total Japanese energy RD&D expenditure in 1997 (up from 35% in 1985), and 71% of total private sector energy RD&D spending (up from 56.5% in 1985). Chart 25 gives details for 1985-97.

Energy conservation attracted substantial RD&D funding from the Austrian government in the period 1993-98. In 1999, 29% of all energy RD&D expenditure went on energy conservation, even though the amount spent on conservation (105 million Schillings) was 20% down in that year from the 1994 level.

In Denmark, 22% of total government energy RD&D spending went towards energy conservation in 1999, and it was estimated that there was a 40% increase in spending in this category in 2000 (to 29% of total energy RD&D expenditure, or almost 96 million Kroner). Government spending on conservation has steadily increased since 1995 in real terms, according to IEA data.

In Finland also, government spending on energy conservation increased rapidly between 1990 and 1997, rising 67% between 1995 and 1997 alone. In 1997, conservation accounted for 43% of the government’s total energy RD&D expenditure, at nearly 202 million Finnmarks. About half the spending on conservation was on industry, and about 35% on the residential and commercial sectors. However, in 1999 there was a complete reversal of the previous expenditure trend – a 40% fall, which alone explained 21 percentage points of the 30% fall in total government energy R&D spending in that year. Chart 26 plots the considerable increase that nevertheless occurred between 1990 and 1999.

So great was the focus of government energy RD&D spending in France on nuclear that expenditure on conservation scarcely figured on charts of budget allocations before 1999. Conservation RD&D actually declined in the 1990s from even its modest 1990 levels. However, in February 1998 the government decided to set aside FFr 575 million in 1999 (compared to FFr 75 million in 1998) for activities concerned with efficient use of energy and the development of renewable energy. The Agence de l’Environnement et de la Maitrise de l’Energie (ADEME) enjoys a sound reputation for its work in both these areas.

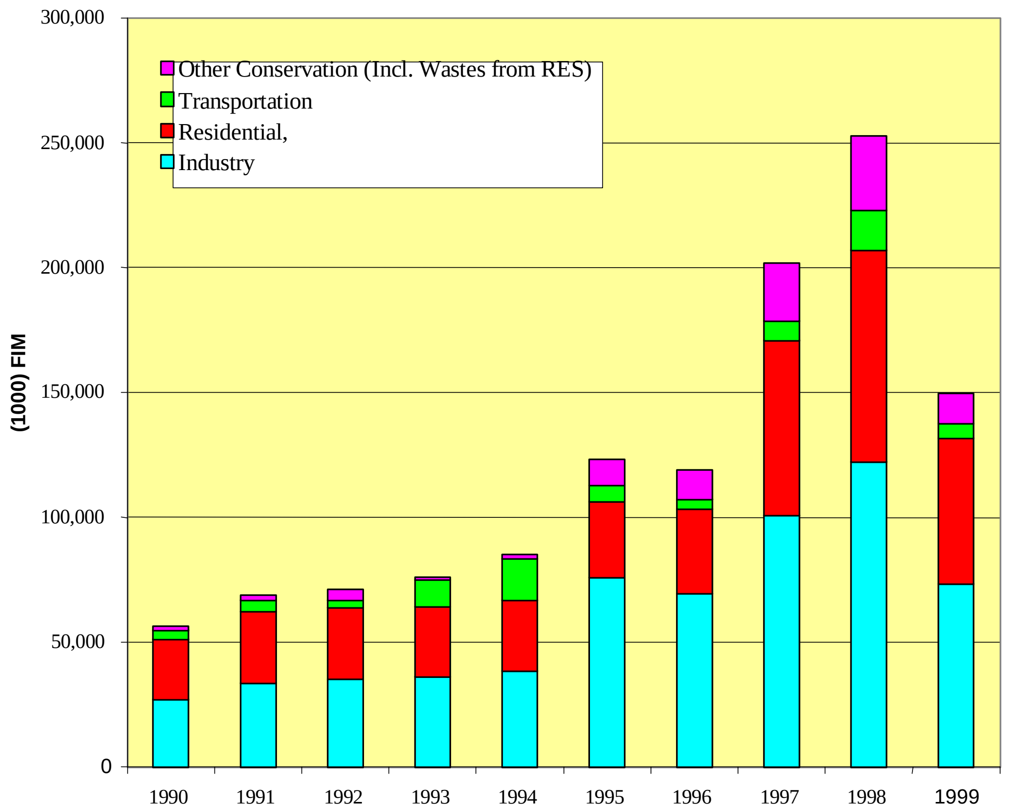

Chart 26. Energy conservation R&D expenditure in Finland, 1990-99.

As previously noted, the country data supplied for Germany do not account separately for spending on renewable energy and on conservation. IEA data suggest that German government spending on conservation has declined in real terms since 1985 (with the exception of the single year 1996). In 1999, spending on conservation RD&D was only 45% of the 1985 level in real terms.

In the Republic of Korea, spending by government on energy efficiency RD&D grew 18-fold between 1985 and 1998 (although it fell 15% from the 1997 level in 1998 under pressure from the Asian financial crisis). Chart 27 provides the details. In 1998, efficiency accounted for 34% of total government spending on energy RD&D. Private sector spending on energy efficiency rose strongly after 1994, and surged in 1996; it slipped back in 1997, but rebounded in 1998. Energy efficiency accounted for 10% of total private sector energy RD&D spending in 1998. The major part of efficiency RD&D funding was directed at the industry sector before 1998, after which this component fell by 80%. Over 80% of conservation RD&D funding in recent years has also usually been directed at the industry sector.

In Spain, government expenditure on energy efficiency RD&D was very low in the late 1980s, but then increased during much of the 1990s (IEA data, constant money). However, in 1998 spending was severely cut back, to only 41% of the 1997 level. Energy efficiency accounted for 3.3% of the government's energy RD&D spending in 1998. Between 1983 and 1998, Spanish governments spent less than 9.3 billion Pesetas on energy efficiency RD&D, less than 5% of all government spending on energy RD&D in the period (about the same amount was spent on nuclear fusion, and fossil fuels received 8.5 times the amount). Of the money spent on energy efficiency RD&D over the period, the industry sector received 72% and transportation 20%. The private electricity sector spent little on R&D on conservation throughout the 1983-98 period.

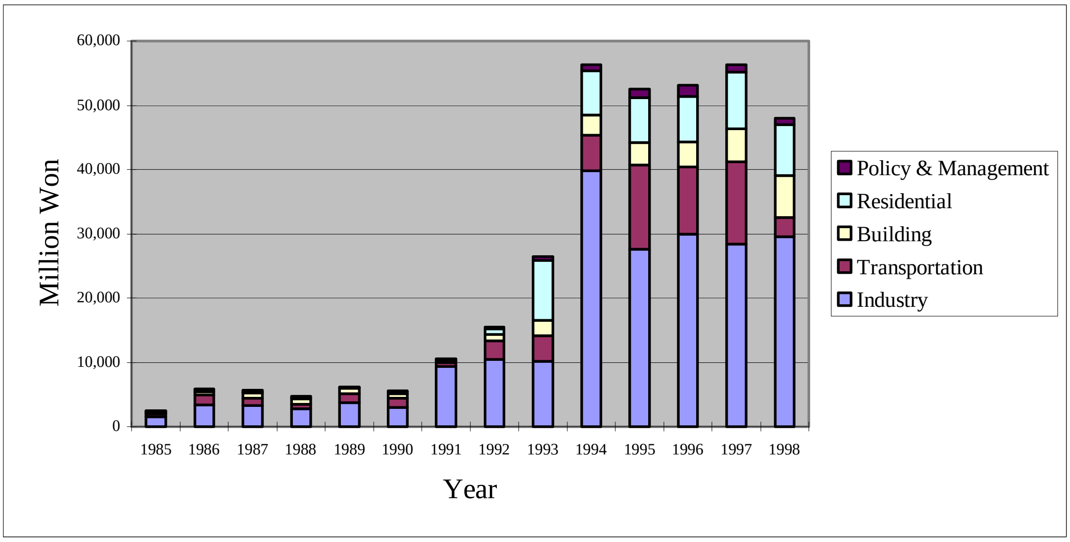

Chart 27. Public sector R&D expenditure on energy efficiency in the Republic of Korea, 1985-98.

In Sweden, government spending on energy conservation RD&D has held fairly steady (although it was relatively low in 1998), representing 34% of total government energy RD&D spending in 1990 and 32% in 1999 (at nearly 187 million Kroner). In 1999, 35% of energy conservation RD&D was allocated to the industry sector, 34% to transportation, 11% to the residential and commercial sectors, and 19% to ‘others’. Chart 28 sets out the evolution for 1990-99.

IEA Data on Government R&D Expenditure on Conservation

IEA data on government expenditure on energy conservation (all expressed in constant local currency terms) show Australia investing very modest amounts under this heading – 6% of its total energy RD&D spending in 1997, and only 71% of the level of expenditure in 1985. In Canada, government spending on conservation RD&D recovered somewhat from its low levels in the late 1980s and early 1990s, but in 1999 was only 52% of the level of 1985.

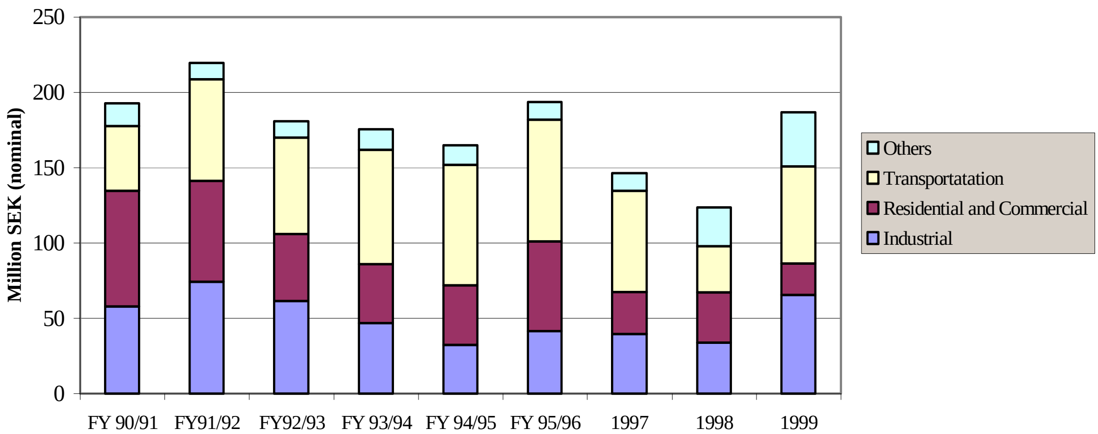

Chart 28. Governmental energy conservation R&D expenditure in Sweden, 1990-99.

Government spending on conservation in Greece surged in 1997 by 2.5 times, to 30% of total government expenditure on energy RD&D. Ireland's very modest government energy RD&D efforts since 1985 have been largely confined to conservation, but even this effort ceased after 1988.

In Italy, government expenditure on energy conservation RD&D has fallen away somewhat from the levels of the late 1980s, but still accounted for 21% of the total spent by government on energy RD&D in 1998. In 1998, 31% of spending on conservation was directed at the industry sector, 29% at transportation, and 24% at the residential and commercial sectors. In the Netherlands, government spending on energy conservation RD&D has remained fairly flat in real terms, but with total energy RD&D spending falling between 1985 and 1998, the proportion allocated to conservation has risen from 21% in 1985 to 37% in 1998.

Norwegian government spending on energy conservation RD&D has collapsed since the mid 1990s, and in 1998 and 1999 was only 10% of the level of 1992. In Portugal, government spending on energy conservation RD&D has fallen away drastically since the early 1990s, and in 1999 was only 7.5% of the 1990 level. Government expenditure on energy conservation RD&D in Turkey has also been running recently at a much lower level than in the 1980s; in 1999 it was only 17% of the 1985 level. In the UK, government expenditure on energy conservation RD&D has dwindled away to almost nothing since 1993.

2.2.5 Other Items of Energy RD&D Expenditure

The 'other' category of energy RD&D expenditure can be large. It was 64% of US federal energy RD&D expenditure in 1998, and 22% of US private sector energy RD&D spending in 1993. In contrast, it was only 3% of Japan's total energy RD&D expenditure in 1997 – of this, 80% was undertaken by the private sector. IEA data for 'Total Other Technology/Research' expenditure suggest that in 1999 it was 43% of US government total energy RD&D expenditure, and 2% of equivalent Japanese government spending. These comparisons alone provide an indication of the limits to what can usefully be stated about the 'other' category in country energy RD&D expenditure figures, and this applies even more strongly when attempting international comparisons. The Study Group has not pursued this topic further here.

The Study Group would have liked to pursue expenditure on fuel cells and hydrogen. In Japan, government spending on hydrogen RD&D has been approaching ¥9 billion per annum, but separate data is not available on hydrogen and/or fuel cell RD&D expenditure, which appears in other categories – for example, under transport in the energy conservation category. A similar concern exists when considering the separate hydrogen RD&D data provided for the Republic of Korea. For other countries, RD&D expenditure data have not been provided for hydrogen or fuel cell expenditure, or are included in the total for fossil fuels or electricity conversion.

Some data do exist for electrical power conversion, transmission and distribution, and storage. The data provided for the USA, Japan, Austria, Denmark, Finland, the Republic of Korea, Spain and Sweden are included in the Annexes. In most of these countries RD&D expenditure in these categories has held up reasonably well in recent years (except in Spain, where there has been a sharp drop since 1994).

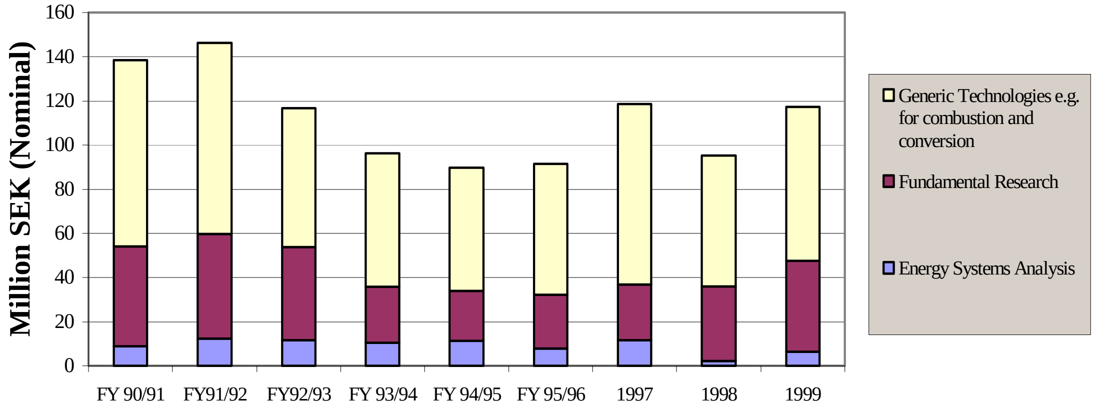

Chart 29. RD&D expenditures on cross-cutting technologies in Sweden by government, 1990-99.

Japan has provided by far the greatest amount of detail on R&D expenditure by electricity utilities – not just on coal, renewable energy, nuclear and conservation. Other categories covered include cost reduction, environmentally related, effective use, storage, power grid, advanced information systems, superconductivity, new materials, and biotechnology. There has been a slight overall decline in electricity utilities' expenditure since 1996 – mainly due to reductions in the nuclear, effective use, and power grid categories.

The Study Group would have liked to provide separate data for basic and applied research, and for development and commercialisation efforts. Sweden was the only country to provide data on fundamental research expenditure, as distinct from energy systems analysis and work on generic technologies (shown in Chart 29).

The final wish of the Study Group when obtaining energy RD&D expenditure data would have been to receive firm evidence relating to whether or not the efficiency of energy RD&D expenditure (inputs versus outputs) had risen, fallen or remained about the same in recent years. There has been some talk of efficiency increasing due to advances in electronic communication and data-processing technologies, even to the point of this perhaps having served to offset reductions in spending, but no evidence of this was forthcoming.

3. COUNTRY AND SECTORAL CONCLUSIONS

There can be little doubt that worldwide energy RD&D expenditure fell between 1985 and 2000. The mere fact that US energy R&D spending fell by over US$3.6 billion between 1985 and 1999 (at 1995 constant prices) is strong evidence for this, given that even now the USA alone accounts for about 40% of global energy RD&D expenditure.

Of the US$3.6 billion decline in the USA, over US$2.6 billion was due to reduced private sector spending, and US$948 million was due to lower federal government expenditure. The reduction in private sector expenditure reflected a fall of around US$1.7 billion in fossil fuel R&D spending, and a US$170 million reduction in spending on nuclear R&D to 1996, with renewable energy, conservation and utilisation R&D spending falling in aggregate by over US$200 million to 1996. The reduction in federal expenditure by 1999 over 1985 was attributable to a US$920 million fall in nuclear R&D spending, a US$240 million reduction in fossil fuel R&D, and a US$53 million fall in 'other' energy R&D. A US$150 million rise in spending on energy conservation R&D did little to offset the decline. Energy R&D spending as a percentage of GDP fell from 0.128% in 1985 to 0.042% in 1999.

For the USA, therefore, total energy RD&D expenditure certainly fell sharply in real terms between 1985 and 1999, and 74% of the reduction was due to lower private sector expenditure. Of the total reduction, 48% was due to reduced spending on fossil fuel RD&D by the private sector. Reduced nuclear R&D spending by both the public and private sectors (of which the public sector was responsible for 83%) probably accounted for a further 28% of the fall in the total expenditure (the qualified wording reflects the absence of firm private sector data after 1997). Lower spending on fossil fuel and nuclear RD&D (noting that federal spending on fossil fuel R&D fell by US$230 million over the period) accounts for 82% of the fall in total US energy R&D spending over the period.

It is not known how much of the fall in fossil fuel R&D spending was accounted for by reduced expenditure on advanced fossil fuel technologies that aimed to be truly 'clean' in the sense of separating and recovering, and/or sequestrating, carbon dioxide and other greenhouse gas emissions. It is known that, although US federal RD&D spending on energy conservation and renewable energy was higher in 1995 than in 1985, it then fell markedly in both categories (by 23% and 15%, respectively) by 1999.

If RD&D expenditure is a precursor to technological advance, a tenet long and widely held in the USA and elsewhere, then the performance of the USA in the energy field is a matter of grave concern. The USA has been identified as the source of over 25% of the world's current annual carbon dioxide emissions from fossil fuel use, while having less than 5% of the world's population. (It should be noted, though, that this has attracted more international comment than the fact that the USA's GDP at purchasing power parity accounts for almost 21% of the world total as conventionally measured.) Whereas it may not be a cause for surprise that spending on conventional fossil fuel RD&D has fallen, at a time when greenhouse gas emissions from human activities are receiving greater political and business attention, it might be thought reasonable to expect more energy RD&D effort in non-fossil fuels – not less.

Furthermore, with US imports of oil rising 48% during the 1990s, and imports of natural gas (overwhelmingly from Canada) more than doubling, to represent 16.5% of annual consumption in 1999,[1] it might have been expected that US energy RD&D spending might show stronger evidence of a desire to increase energy security – whether by increased efforts in RD&D on fossil fuels, on non-fossil fuels, or on energy conservation. None of this seems to have happened. Given the strength of US capacities in technology innovation and diffusion it is unfortunate that more effort is not being made on renewable energies, on the next generation of nuclear energy, on carbon sequestration, and on energy efficiency and conservation technologies (especially end-use applications).

If Canada is included, in order to provide consideration of total North American energy RD&D efforts, little further encouragement can be derived. Some increase occurred in the energy efficiency RD&D of electricity utilities and the private sector in the period 1983-95 (according to Runci, cited earlier), and the Ballard corporation has been a leading player in fuel cell technology developments, but overall private sector energy RD&D spending has been flat. Public sector spending has declined, by 18% between 1995 and 1999 alone.

For Asia, this report has obtained two detailed new country reports – for Japan and the Republic of Korea. Unfortunately, in view of the possible impacts of the Asian financial crisis of 1997 and the ongoing economic difficulties in Japan, the data for Japan only go up to 1997 and for the Republic of Korea up to 1998. There are some signs in the Korean report in the 1998 figures that the regional financial crisis had some adverse effects – although private sector energy RD&D expenditure was sustained in most categories and only fell 6% overall.

Based upon these two countries, which are the major energy RD&D investors in the region, the picture is much more robust than that in North America almost across the board. However, renewable energy RD&D in Japan has not been a powerful motor (in 1997 it accounted for only 3.9% of total energy RD&D spending, being only 10% of that spent on nuclear RD&D), and in the Republic of Korea public sector spending in this category fell heavily in 1998. It should be noted that, although Japan has only 2% of the world's population, it accounts for about 5.5% of global carbon dioxide emissions from fossil fuel use.

In Western Europe, the only other region for which significant new country data were obtained, the pattern of energy RD&D expenditure is very mixed. In Belgium, Germany, Italy, the Netherlands, Portugal, Spain and the UK energy RD&D spending has fallen in real terms – in most cases very markedly since 1985. Expenditure in Norway and Switzerland appears to have fallen more recently, since 1995 (although in the case of Norway investment in carbon sequestration has increased). Reduced spending on nuclear power RD&D is a major cause, but spending on energy efficiency and renewable energy RD&D have also fallen significantly in most cases.

Austria, Denmark, France and Sweden provide a more mixed pattern, with fluctuations over the period but no pattern of extended decline and some evidence of recent real increases. Finland exhibited a quite strong upward trend through the 1990s until 1998, but there was a sharp fall in 1999. The European Union's programmes have expanded their efforts on energy efficiency and renewable energy, although energy has taken a declining share of the five successive Framework Programmes.

Given the strong rhetoric from Western European countries on the need to curb and reduce greenhouse gas emissions and raise energy efficiency, there is a surprising lack of clear evidence that energy RD&D efforts are being made in the relevant areas (with the exception of the EU programmes). The EU's 15 member countries account for about 6.4% of the world's population, but over 14% of current annual carbon dioxide emissions from fossil fuel use. In only the five countries where RD&D expenditure has tended to rise is there evidence of a link between words and action (and in two of them – Austria and Denmark – carbon emissions from fossil fuel use rose quite rapidly in the 1990s nonetheless).

As 12 of the 15 EU Member countries had at the end of the 1990s been unable to achieve a central aim of the 1992 UN Climate Convention of returning their greenhouse gas emissions back to 1990 levels, and the success of the remaining three countries was widely regarded as somewhat fortuitous, it might have been expected that a greater sense of urgency would have been demonstrated through relevant energy RD&D expenditures. This line of argument might be thought to apply *a fortiori* to those countries which endorsed the quantified greenhouse gas emissions limitation and reduction commitments set out in the Kyoto Protocol in December 1997.

The EU is also anticipating a sharp rise in import dependency for all three fossil fuels. In 2000, EU coal import dependency was about 45%, but by 2020 it is expected to be 65%. Oil import dependency in 2000 was nearly 80%, and in 2020 it is expected to be nearly 95%. Natural gas import dependency in 2000 was 40%, and in 2020 it is expected to be over 65%.[2] It might have been expected that concern about this outlook would have resulted in an increase in relevant energy RD&D expenditures at the EU and member state levels.

There has been little evidence in the energy technology RD&D data obtained of spending on international energy technology transfer. The only two countries to supply specific detail of such expenditure were Austria (45 million Schillings in 1998 to non-IEA international projects) and the Republic of Korea (various amounts between 1995-98). More general information was supplied for Sweden, where there is participation in international programmes under the auspices of the IEA, a National Energy Administration programme to assist the Baltic States, and several programmes run by the International Development Agency focussed on the needs of developing countries.

Some spending under this heading may have been allocated under different categories in other country reports. However, the lack of detail on spending in this area is surprising, given that the UN Climate Convention requires developed countries to engage in transfer of technology to developing countries. Article 4.7 of the Convention states: "The extent to which developing country parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country parties of their commitments under the Convention related to financial resources and transfer of technology, and will take fully into account that economic and social development, and poverty eradication, are the first and overriding priorities of the developing country parties."

It has also been suggested in various reports and studies[3] that much more could and should be done by industrialised countries to support 'leapfrogging' in technology use in developing countries, as well as technology cost buy-down projects and the build up of research know-how. Again, the industrialised country reports presented here show no evidence of support for this line of thought.

However, some participants in the Study Group's work wished to emphasise the importance of information sharing and knowledge transfer, and believe that advances in information technology have considerably enhanced such transfers and the prospects for their increase in the future. Within some regions, such as the European Union, it is clear that such sharing and transfers do take place. However, the Study Group was not provided with information on how effective or efficient they are.

References

1. BP Statistical Review of US Energy, June 2001.
2. European Commission: "Energy in Europe: Economic Foundations for Energy Policy", Special Issue, Shared Analysis Project, December 1999, fig 6-1, p 88.
3. See, Jefferson M: "Energy Policies for Sustainable Development", chap 12 in "World Energy Assessment: Energy and the Challenge of Sustainability", UNDP, New York, 2000, pp 438-441.

4. OVERALL CONCLUSIONS

In preparing this report, the Study Group has considered the energy RD&D expenditures of some 23 countries during all or most of the period 1985-2000. Of these, the performance of 18 countries has been examined with particular care. New reports containing comprehensive and detailed public and private sector spending data were provided for only four countries, but detailed reports of a more restricted nature were obtained from four additional countries. Some data were also received from a further seven countries. IEA data on energy technology RD&D spending by governments have also been examined, as have country reports produced by the Pacific Northwest National Laboratory.

The Study Group found that in about half of the 18 countries considered in detail total government energy RD&D expenditure declined significantly in real terms between 1985 and 1997-2000. Total government energy RD&D spending in the other countries examined remained stable or increased.

There is therefore no foundation for reports that government energy RD&D has been in comprehensive decline over the period. However, US federal government energy RD&D spending – about 40% of the world total – has markedly declined. Thus it seems likely that the world total of government energy RD&D spending has fallen, because of the large weight of the USA in the whole. Nevertheless, the second largest government budget for energy RD&D – that of Japan – expanded markedly over the period (by 45%).

The performance of the private sector is much more difficult to gauge. There have been anecdotal reports (reinforced by detailed data for the USA) that private sector energy RD&D spending declined sharply during the 1990s, as low energy prices, market liberalisation and privatisation/restructuring left their mark. Detailed private sector expenditure data were obtained for five countries, and these show that only in the USA was a sharp decline evident. However, the anecdotal reports have been quite widespread, and it may be that it is too early for the data to reflect recent trends in the other countries, one way or the other.

The Study Group has not been able to obtain any evidence on improvements in the efficiency of energy RD&D expenditure by either the public or private sector, or on whether some of the perceived decline in private sector energy RD&D spending has been made up by an increase in outsourcing, which is not captured in the data.

In the cases of Japan and the Republic of Korea, the effects of the Asian financial crisis and subsequent economic turbulence cannot be fully judged from the data available, although the data end-points confirm that private sector expenditure was massively higher at the end of the period than at the beginning.

Cuts in energy RD&D expenditure have fallen disproportionately on fossil fuels and nuclear (fission and fusion). It cannot be clearly ascertained whether it is spending on conventional fossil fuel technologies which has fallen most, although anecdotal reports hold to this view. Heavy cutbacks in nuclear RD&D spending reflect public and political concerns about operational safety, waste disposal and proliferation in many countries. But if it is the purpose of RD&D to achieve technological advances to overcome perceived problems, and the historic record suggests considerable success in this endeavour, then it is surprising and disappointing that there appears to have been such widespread unwillingness to press forward with nuclear RD&D efforts in the hope and expectation of overcoming the challenges.

A few countries, notably Japan and France, have continued to invest heavily in nuclear RD&D. This is very much a minority position. In these two countries, spending on renewable energy RD&D has been very low (despite the solar photovoltaics and fuel cell programmes in Japan). In general, RD&D expenditure on energy efficiency and renewable energy in almost all the countries examined has seemed low in relation to present challenges and likely future needs.

Meeting the demands of sustainability – such as providing access to modern energy services to those currently without (whether through distributed generation and solar photovoltaics or by grid or pipeline systems) and reducing the adverse environmental impacts of energy use – will require major improvements in the efficiency of energy use, much higher reliance on renewable energy technologies, and cleaner fossil fuel technologies (a term which encompasses technologies that prevent emissions of greenhouse gases from fossil fuel use to the atmosphere). New technologies will be needed, as well as the accelerated deployment of commercial technologies.

There is a widespread and, in the Study Group's view, justified concern that seemingly robust technologies are not being developed and diffused quickly enough or on a sufficiently large scale to meet the challenges of sustainability. There is a need to accelerate the energy innovation process by all effective means, including appropriate public policies and well-conceived, stable government-funded research programmes. Pricing energy to cover full marginal costs and effective metering and collection systems are, in the view of WEC, also central to this objective.

It is recognised that government funding of research efforts can sometimes be unstable and too strongly influenced by politics and short-term circumstances, even though governments can be well placed to support basic research. By the same measure, we recognise that many commercial firms may be reluctant to make the long-term strategic commitment to the spending programmes required for research and development, although they can be well placed to make incremental improvements in technologies. At the deployment (or commercialisation) stage there may be serious problems of uptake, but despite the long lead-times that often exist for market growth the role for commercial enterprises is more clear-cut at this stage than is any role for governments. Looking at country data on energy RD&D spending over the past 15 years or so does not give the impression that a clear strategic overview and purpose lies behind the discernible patterns.

Based on its examination of energy RD&D spending data for a range of countries, the Study Group believes that the conclusion drawn by the US President's Committee of Advisors on Science and Technology (PCAST) in its 1997 report "Federal Energy Research and Development for the Challenges of the Twenty-First Century" has wider validity: "Energy RD&D programmes, taken as a whole, are not commensurate in scope and scale with the energy challenges and opportunities the twenty-first century will present."

The Study Group also concludes, as PCAST did in its 1999 report "Powerful Partnerships", that there is substantial scope for strengthening international cooperation in energy RD&D. It is particularly important that industrialised countries make greater efforts to deploy advanced, environmentally-friendly energy technologies in their domestic markets, both for environmental mitigation purposes and to 'buy-down' technology costs to permit faster diffusion of appropriate technologies elsewhere in the world. The latter would help to serve two purposes: faster access to modern energy services for all; and reduced environmental pollution and greenhouse gas emissions around the world.

There is also scope for helping developing countries build up their own capacities to operate, maintain, and eventually innovate, manufacture and export environmentally-friendly technologies. Ideally, industrialised countries would devote more resources to efficient and environmentally-friendly technologies which would specifically meet the needs of those in the developing world, where most of the world's incremental energy requirements are expected to arise.

In its examination of countries' energy RD&D expenditures, the Study Group has seen little which gives confidence that these international aspects and opportunities are being given sufficient consideration. Indeed, the US academic literature suggests that the US private sector has a low RD&D effort in the energy field by comparison with most US industrial sectors.[1] We have been unable to ascertain whether this is true for other countries.

The Study Group takes some encouragement, nevertheless, from some of the recommendations in the May 2001 report of the US National Energy Policy Development Group to the US President. Several of these recognise the importance of technology innovation and its wider deployment, namely:

- Public awareness programmes about energy, including information on energy's compatibility with a clean environment.
- A review of current funding and historic performance of energy efficiency R&D programmes, and proposals for appropriate funding of those R&D programmes that are performance-based and modelled on public-private partnerships.
- The promotion of congestion mitigation technologies.
- Tax credits for new hybrid fuel-cell vehicles and advanced bus propulsion technologies.
- The establishment of a national priority for improving energy efficiency.
- Improvements in oil and gas exploration technology, and the promotion of enhanced oil and gas recovery through new technology.
- The further development of clean coal technologies.
- A permanent extension of existing R&D tax credits.
- Regulatory approaches which will encourage advances in environmental technology.
- The encouragement of safe and environmentally sound new advanced technology and next generation nuclear reactors.
- The promotion of renewable energy and increased support for R&D of renewable energy resources, a review of current funding and historic performance of renewable energy and alternative energy R&D programmes, and the use of tax credits and exemptions to support renewable energy.
- The development of next generation technology – including hydrogen and fusion.

These are, we believe, encouraging remarks in a world where energy RD&D spending has too often been in decline or not well allocated for meeting the needs of sustainable development.

The Study Group's conclusions are therefore mixed, in the sense that that not all countries or energy sectors have exhibited the same trends in RD&D spending. But a degree of pessimism about the effort being put into energy RD&D is justified, given the challenges the world faces in the present century. We believe that energy RD&D effort, if well applied, provides important insurance against future risks.[2]

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1. Margolis RM & Kammen DM: "Underinvestment: The Energy Technology and R&D Policy Challenge", *Science*, 285, 30 July 1999, pp 690-692. Also, Dooley JJ: "Energy Research and Development in the United States", Report PNNL-12188, 1999, Pacific Northwest National Laboratory/Battelle Memorial Institute, USA.
2. Schock RN et al: "How Much is Energy Research & Development Worth as Insurance?", Amer. Rev. Energy Environ., 1999, 24, pp 487-512.

5. RECOMMENDATIONS

The Study Group make the following recommendations:

1. Energy RD&D spending and technology transfer need to be increased in almost every country, and internationally, in order to meet the requirements of those without modern energy services more quickly, and to provide the efficient, reliable and clean energy-related technologies which are required everywhere. The challenges of sustainable development, including climate change mitigation, provide critically important incentives for additional RD&D effort. Governments and the private sector both need to increase their efforts in this regard. There is also a need to spend the money wisely, and to have a better understanding of the level and breakdown of existing expenditure. It is recommended that the over-arching goal should be a clearer strategic direction behind energy RD&D spending in order to achieve sustainable development.
2. The priorities for RD&D effort within that over-arching goal should therefore be the advancement of technologies which: (a) raise efficiency in energy provision and end-use; (b) promote the faster deployment of locally appropriate renewable energy systems that do not themselves have serious adverse environmental effects; (c) respond to public concerns about the operational safety, waste disposal, proliferation risks and costs of nuclear power; and (d) allow carbon sequestration.
3. Regional collaboration in energy RD&D effort should be encouraged, and to this end WEC Member Committees should provide data on technology transfer and exchange to WEC's Global Energy Information System (GEIS) for worldwide distribution.
4. All governments engaged in energy RD&D (directly or indirectly) should as a matter of urgency produce detailed energy RD&D expenditure data in local currency, both in current prices and, at internationally agreed five-year intervals, in constant prices. Differentiation should be made between spending on basic and applied research, on development and commercialisation, and on RD&D for conventional and advanced fossil fuel technologies. Carbon sequestration, hydrogen and fuel cell RD&D spending should be identified. Changes in definitions and their implications should be clearly stated as they occur. The International Energy Agency, which already produces the most comprehensive international energy technology R&D data series, could perform a useful role in both improving the quality of energy RD&D expenditure statistics produced and increasing the number of countries producing them.
5. In countries where private sector energy RD&D spending is taking place, governments should, as soon as possible, require the relevant private sector organisations to provide in confidence to the appropriate national statistical authority at annual intervals a record of their energy RD&D expenditure under categories to be internationally agreed. The names of individual corporations would remain confidential for competitive reasons.
6. Governments which have reduced their energy RD&D budgets in recent years should increase them, both in total and in selected individual components which aim to meet the challenges of the present century.
7. Governments which have maintained or increased their energy RD&D expenditure are asked to review the balance of their expenditure to ensure that

energy efficiency (especially in end-use technologies), locally appropriate renewable energy sources and technologies, advanced fossil fuel technologies (especially those that can separate, recover and sequester greenhouse gas emissions), and safe nuclear technologies are given the appropriate level of support.

8. The balance of government effort between, on the one hand, basic research on technology which is likely to be robust in the long term, and, on the other hand, short-term applied technological development, should also be reviewed – with the emphasis shifting to the former where feasible.
9. Governments are invited to take a leadership role in raising awareness, through education and information campaigns, of the need for more (and more effective) private sector energy RD&D expenditure, in order to ensure that the scope and scale of the effort is commensurate with the emerging needs and challenges of the twenty-first century.
10. Greater international cooperation in energy RD&D efforts should be encouraged by governments, to accelerate access to modern energy services for those currently without them, to improve the reliability and efficiency of those services already provided, and to permit the fulfilment of international obligations to safeguard ecosystems and avoid significant global climate change due to human activities.
11. In order to stimulate private investment, including venture capital investment, in energy-related RD&D which supports energy quality, eco-efficiency and renewable energy, market mechanisms that complement the existing and expected energy mix – such as energy set-asides[1] – should be created.
12. Finally, it is recommended that the World Energy Council, through the information services it provides to its global membership, the dissemination of this report, and its work on identifying those energy technologies believed to be robust across a wide range of scenarios, seeks to encourage a carefully considered, selective resurgence in energy RD&D expenditure in both the public and private sectors.

Footnote

1. 'Set-asides' is a term relating to renewable energy borrowed from the US legislative process concerning the restructuring of energy markets, including provisions that support renewable energy. Some bills require that commercial electricity generators produce a minimum 'set-aside' percentage of total electricity sold from renewable energy sources. The Renewable Portfolio Standard (RPS) introduced or proposed in several US states is an outcome of this policy. The model can also include the issue of tradeable renewable energy credits in proportion to renewable energy production levels. The UK's Renewable Energy Obligation, which aims to achieve 10% of electricity generation from renewable energy sources by 2010 (a seemingly extremely challenging target), is another manifestation of renewable energy set-asides. The idea is to create a system through which more widespread deployment of clean, renewable energy resources would be ensured, dependent upon market mechanisms in the competition between different sources of supply.