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Energy R&D in the United Kingdom

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United Kingdom

Population: 59 million[1]
GDP 1998: $1.25 trillion (£ 920 billion)[2]

National R&D Effort 1996:

- $22.3 billion (£ 16 billion)[3]
- R&D as a percentage of GDP: 1.94%
- Percentage of R&D expenditure financed by:
  - -Public sector: 32%
  - -Private sector: 68%

Government Energy R&D Expenditure 1998: $82 million (£ 60 million)[4]

Overview

Analytical Findings
National S&T Funding Goals
National Energy Policy and Energy Overview
Energy R&D Programs

Summary of Analytical Findings

A major political/ideological shift gained momentum in the UK in the late 1970s under the government of Margaret Thatcher. At that time, the British government embarked on a broad program of deregulation and privatization of key industries (including the gas and electricity industries) as part of an effort to reduce the role of government in the economy. While many economic benefits (e.g., lower taxes and lower consumer prices for a variety of products including energy) have resulted, deregulation and the introduction of competition in formerly-regulated industries have introduced a high degree of turmoil into the UK's overall research and development enterprise. For example, government support for R&D has declined by more than 15% since the mid-1980s, while private sector R&D has fallen by as much as 80% in some industries, and by approximately 10% overall. The United Kingdom currently spends approximately 1.9% of GDP on R&D.

More so than most other leading industrialized countries, the United Kingdom now relies on mechanisms other than direct research funding as a means of promoting R&D. Tax credits, public-private partnerships, and government-sponsored industry working groups now figure as prominently as direct R&D funding as a means of promoting the development and adoption of new technology. The British government believes that decisions regarding energy R&D are largely the concern of the private sector energy industries.

The shift away from public R&D funding also reflects the fact that commercial return on technology investments is a primary focus of British technology policy which strongly emphasizes economic competitiveness. Private and public sector investments aim to move technologies to market, in the UK and abroad, and to realize relatively near-term economic returns. Given this focus, some basic research and long-term, high risk projects have fared especially poorly compared with technology improvement, demonstration, and deployment initiatives.

R&D in selected socioeconomic areas has received increasing public investments. Health research rose by 278% (to $1.2 billion) between 1987 and 1996, while basic science has recently grown by 20% (to $2.5 billion). Among the top ten industrial R&D sponsors, only the pharmaceutical industry has increased its R&D investments—by 49% (to $2.7 billion).

University-based science in the UK has suffered severely over the past two decades of declining investment in support for research and scientific equipment and facilities. In an effort to revive university science, the British government, in an atypical partnership with a private, non-profit organization, the Wellcome Trust, will invest $2.3 billion over the next three years to rebuild the academic science base. $665 million (29%) of the funds will be furnished by the Wellcome Trust.

Energy R&D investments in the UK have declined sharply. The UK's Department of Energy, which housed the majority of the government's energy R&D activities, was

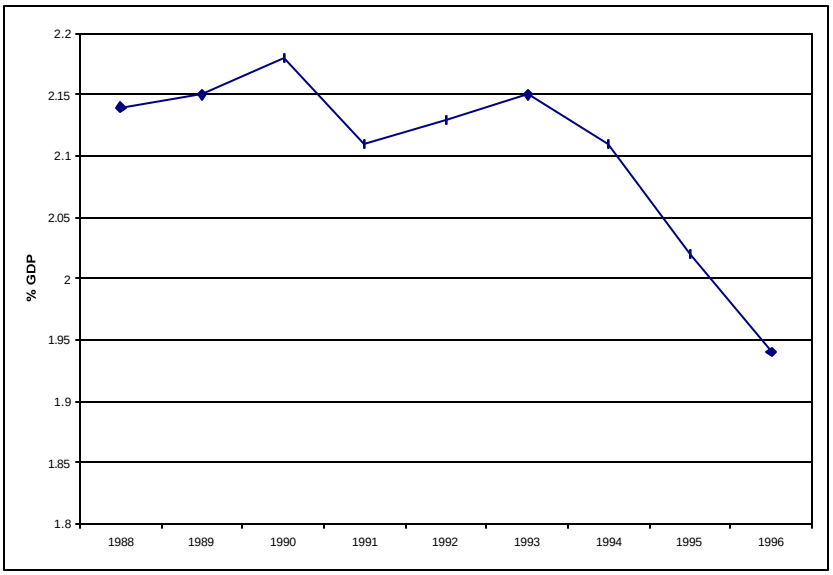
abolished in 1992, and its functions were largely dismantled. Government investments in energy R&D fell by 90% (to a level of $48 million) in real terms between 1987 and 1999. As a percentage of total government R&D investment, energy has fallen from approximately 4.4% in 1987 to 0.7% in 1997. Remaining energy R&D-related activities now fall largely under the auspices of the Department of Trade and Industry and focus on the further development and improvement of existing technologies and on their commercial deployment. The Non-Fossil Fuel Obligation, a policy that requires electricity producers to use non carbon-based primary energy sources for a portion of their generation, has become a major vehicle for the promotion of R&D and clean energy development in the absence of direct government research funding. Private sector energy R&D has also declined significantly over the same period—falling by approximately 40% (to $214 million) in the gas and electricity industries and by 55% (to $93 million) in the oil and coal industries.

National Science and Technology Effort and Funding Goals

The election of Margaret Thatcher's Conservative government in the late 1970s began a period of government downsizing and liberalization of key British industries that persists to the present. Whereas the 1970s may be regarded by many as the high water mark of the postwar welfare state in Britain, characterized by heavy regulation and high taxes, prices, and unemployment, over the ensuing decades, the United Kingdom has come to represent the vanguard of deregulation and laissez faire policies.[5]

The ideological shift in the United Kingdom from welfare state to free market economics has had many important effects on the country, among them the introduction of considerable turmoil in the overall research and development enterprise. Figure 2 shows that between 1988 and 1996, for example, the government's direct support for R&D declined from 35.4% to 31.8% of the national (i.e., combined public and private sector) total, as R&D decision-making has been left increasingly to the private sector. Yet, as Figure 1 shows, as a percentage of GDP, overall R&D investments in the UK have declined significantly in recent years from 2.14% to 1.94%. The liberalization of major industries (e.g., airlines, telecommunications, and energy) and economic integration with the European Union have placed mounting pressure on firms' R&D expenditures. As a result, the UK now ranks fifth among G-7 countries as a sponsor of R&D.[6] Moreover, between 1986 and 1996, for example, the portion of the United Kingdom's R&D effort accounted for by public investment fell by 14% in real terms, from $9.6 billion to $8.3 billion.[7]

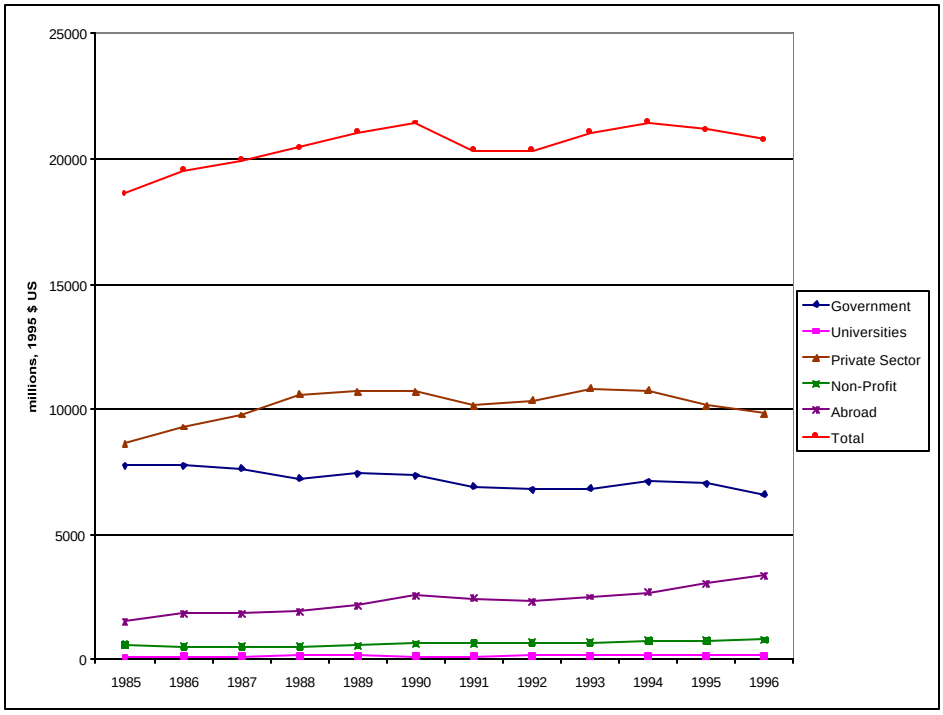
Figure 1. R&D as a Percentage of GDP, 1988-1996[8]



Private sector R&D in many key technology areas has also declined significantly in recent years. With the exception of the pharmaceuticals industry, research expenditures fell in real terms in each of the R&D-intensive industries shown in Figure 3, below.

Among the industries that experienced the sharpest reductions in R&D investment were the extractive industries (including oil and coal production), where investments fell by 56% to $93 million between 1989 and 1996, and the electricity, gas, and water supply industries, where investment fell by 40% to $214 million over the same period.[9]

Figure 2. Expenditures on R&D in the United Kingdom by Funding Source, 1985-1996



A major factor that has contributed to the recent decline in private sector R&D in the UK has been the country's relatively volatile macroeconomic conditions over the past two decades; at various times, high inflation rates, large fluctuations in demand, and large budget deficits have all discouraged long-term investment. Perceptions of volatility have encouraged companies and financial institutions to place greater emphasis on short-term gains and to steer away from longer-term R&D projects. This emphasis on short-term gains has had a particularly great impact on the R&D activities of small and medium-sized companies, which typically have neither the internal capital nor the access to external sources of finance that larger corporations have. Yet even large corporations that have historically been the largest sponsors of private sector R&D have scaled back their research efforts significantly in most industries, considering shareholders' dividend expectations and the rising tide of takeover activity in the UK's increasingly liberalized marketplace.[10]

The federal government's downsizing of its support for R&D over the past two decades has also compounded the decline of R&D performance and funding by private enterprises. Between 1981 and 1995, for example, the UK's total private sector R&D

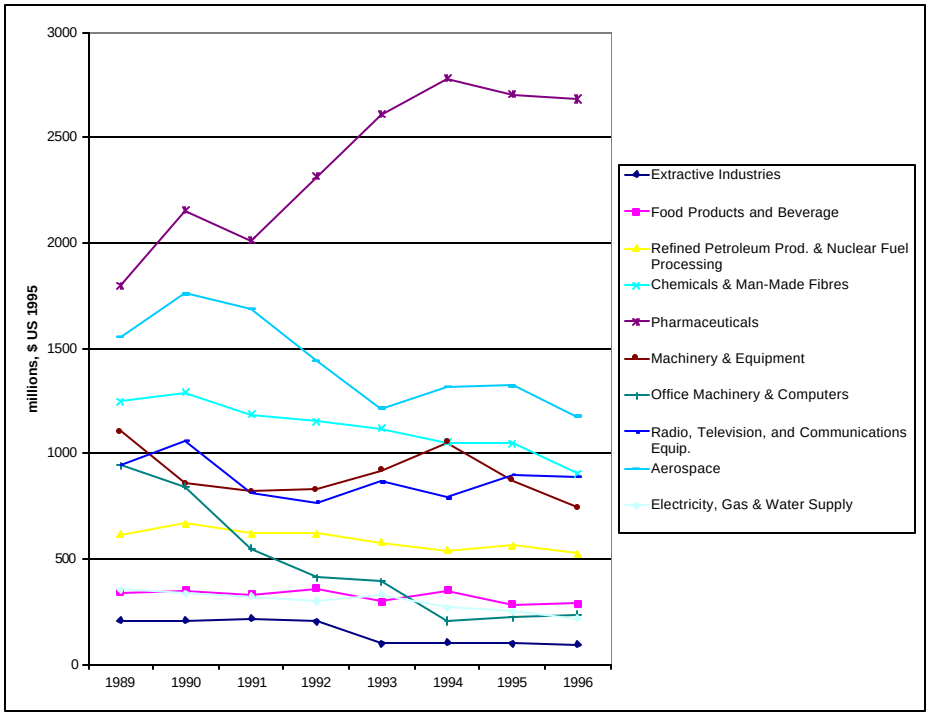
investment as a percentage of GDP fell from approximately 1.5% to 1.3%, causing Britain to fall from the third to the fifth rank among G-7 countries as a private R&D sponsor. Despite its aim of privatizing the conduct of research via reliance on market mechanisms to determine the appropriate levels and directions of investment in innovation, the British government acknowledges that this policy has not worked well and that the country's R&D has reached a critical level of ill health and a condition that threatens future economic growth and international competitiveness.[11]

The government has responded with a series of measures aimed at changing the UK's incentive structure as it affects private R&D. For example, the 1997 Corporation Tax Reform removed a bias in the tax system that favored the distribution, rather than retention, of profits. Other initiatives, such as the Department of Trade and Industry's SMART program, provide grants for feasibility studies and product development; a Small Firms Loan Guarantee Scheme aims to improve small high-tech firms' access to finance; and the government's Business Links program serves as a clearinghouse, providing information, advice and technical assistance to help firms secure R&D funding from private sources.[12] Nonetheless, the most recent data suggest that the UK's overall R&D enterprise—having declined by 7% in real terms between 1989 and 1996—remains anemic and requires renewed commitments to reinvestment.[13]

The British government has also established several government-industry working groups that focus on specific barriers to innovation faced by industry. Working groups focus, for example, on the financing and management of high-technology start-ups and aim to identify and eliminate barriers to high-technology industry growth, including problems associated with the acquisition of capital (especially for smaller firms) and with the domestic tax environment for technology firms. The Investment Working Party, chaired by the Minister for Science, Energy, and Industry, includes representatives from small and large firms in the manufacturing and service industries and serves as a clearinghouse to identify ways that U.K. business can improve its performance in innovation.[14]

Since 1994, a key element of the government's R&D effort has been the Technology Foresight Programme, housed in the Office of Science and Technology of the Department of Trade and Industry. The Foresight Programme is a government-sponsored forum in which representatives from federal agencies, industry, and academia meet to identify the UK's technology priorities in fifteen key economic areas, including energy. The Programme has provided over $300 million for collaborative research projects since its inception. The Foresight Programme, like many of the other government-sponsored programs described above, underscores the British government's continued reliance on market mechanisms and reluctance to intervene in the economy directly to shore up the country's R&D infrastructure. While several of the programs described here have been successful in achieving their intended aims, most have tended to favor the refinement and commercial deployment of technologies already in the development process. Thus, longer-term projects, riskier ventures with less certain payoffs, and the basic research end of the innovation process in many respects continue to languish under the current orientation of the British R&D system.

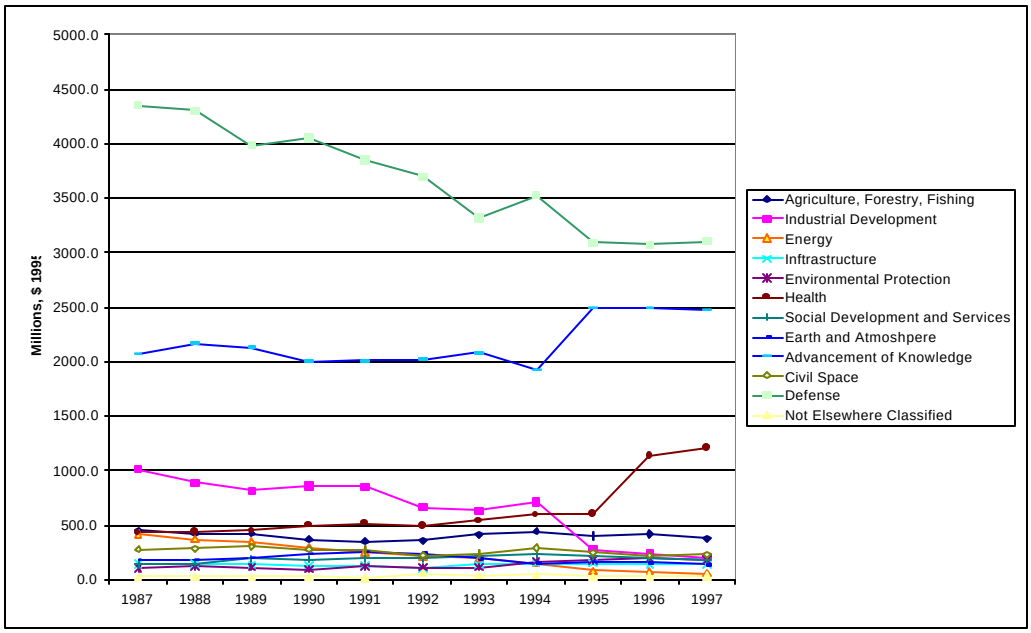
Figure 3. Selected UK Industries' R&D Expenditures 1989-1996



Recognizing these shortcomings, the government has begun to take action to reverse the trend in support for research. One of its most important objectives in this regard is the refurbishment of the university-based research infrastructure. Over the next three years (1999-2002), the government, in partnership with the Wellcome Trust—the United Kingdom's largest charitable funder of scientific research—will invest $2.3 billion ($665 million of which will come from the Wellcome Trust) in the construction and renovation of university research facilities, and the purchase of new equipment through a new public-private sector initiative called the Joint Infrastructure Fund. While the Joint Infrastructure Fund will focus on the full spectrum of university-based scientific research, the Wellcome Trust's contributions to the Fund will be devoted primarily to the development of facilities in the biomedical and related scientific fields.[15]

As Figure 4 shows, the overall decline in R&D investment has had different implications for different research areas. Defense R&D, for example, has been one of the hardest hit areas over the past decade. While the defense R&D budget had begun to decline in the late 1980s, the rate of decline accelerated after 1991, in the aftermath of both the Cold War and the Gulf War. Between 1986 and 1996, defense R&D spending fell by 30% in real terms, before recovering slightly, by 0.8%, in 1997. Budget reductions of more than 80% in both the industrial development and energy areas, reflect the government's policy shift in favor of a reduction of its intervention in the economy.

Figure 4. Government R&D Expenditure by Socio-Economic Area 1986-1997

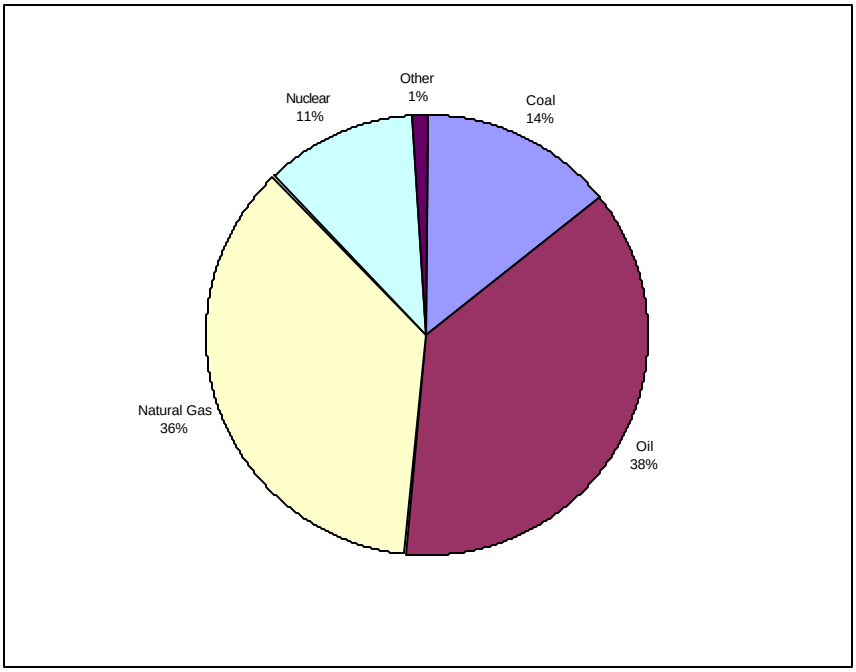


A few research areas have, on the other hand, enjoyed increasing government support in recent years. For instance, after a long period of flat and falling budgets, government investment in general university funds ("advancement of knowledge") jumped 23% between 1993-1994. The Labour government, which took office in 1997, reiterated its predecessor's stated commitment to improving the science base. In addition to its support for university-based science, the government is aiming to promote the commercialization of university research by creating incentives for researchers to partner with industry and for entrepreneurs to start new, technology-oriented small businesses.[16] The government's partnership with the Wellcome Trust to rebuild the country's university science infrastructure is a critical underlying component of this task.

In contrast to the reductions in R&D support observed in many areas, government funding for health research has also grown substantially, by 60% in real terms since 1991. This trend stands at odds with the United Kingdom's general policy of reduced government roles in research. The government's increasing emphasis on R&D funding in the health area reflects the major potential benefits to the economy that the current advances in the health and biotechnology fields hold. The government's investments in health science and technology aim to provide the necessary basic infrastructure and expertise that leadership in the health industries require. For example, the United Kingdom's pharmaceutical industry has historically been a world leader; yet recent surveys of pharmaceutical industry executives and researchers have indicated that a lack of qualified scientific personnel has become a limiting factor to the future strength of the U.K.'s leadership and competitiveness in this and other key industries.[17]

National Energy Policy and Energy Overview

Figure 5. Total Primary Energy Consumption (10 Quads), 1997[18]



Energy Snapshot 1997[19]

Net Dependence on Energy Imports: 20%	Energy-Related Carbon Emissions: 155 million metric tons
Energy Consumption per Capita: 175 million Btu	Carbon Emissions per Capita: 2.7 metric tons
"Kyoto Commitment": 12.5% reduction in greenhouse gas emissions from 1990 levels by 2008-1012	Total Primary Energy Consumption 1996: 10 quadrillion Btu

Energy Policy. The United Kingdom's overarching energy policy objective is to ensure secure, diverse, and sustainable supplies of energy at competitive prices. The government believes that, in this regard, liberalized, competitive markets offer consumers the greatest benefit. In the government's view, properly functioning competitive markets are more flexible and responsive than non-competitive markets, and thus contribute to the achievement of energy security and diversity.[20]

Overall, the deregulation of energy in the UK (discussed in greater detail below) has yielded net benefits for consumers, although the distribution of benefits among consumer classes has been uneven. Although residential consumers of electricity and gas have experienced lower real energy prices since privatization and deregulation, the gains to commercial and industrial consumers have been substantially greater (as much as 50-

60%).[21] From an environmental perspective, the liberalization of the energy industries has also yielded important benefits by creating a political and economic environment that favored natural gas over coal, the traditional foundation of the British electricity industry. The rapid "dash to gas" by electricity generating companies in the UK ultimately prompted the government to issue a temporary moratorium in 1998 (which remains in effect as of early 2000) on the construction of new gas-fired plants. Although the government has justified the gas moratorium on grounds of energy security and concerns for the country's rising dependence on gas imports from Russia and Algeria, many analysts view this policy action primarily as an effort to stem the decline of the domestic coal industry and support both the industry and its workers.[22]

The British government also believes that decisions regarding energy R&D are largely the concern of the energy industries. In fact, over the past decade, government energy R&D investments have fallen by more than 90% in real terms, as a result of a deliberate strategy on the part of the government to reduce its interventions in the marketplace and its overall budget outlays. For example, the Department of Energy, a major historic sponsor of scientific research, was dismantled in 1992.[23] Most of the Department's functions were abolished, while those that were retained (such as responsibility for a downsized energy R&D portfolio) were distributed among other cabinet Departments, most notably the Department of Trade and Industry.

The dismantling of the Department of Energy and the downsizing of overall government R&D investments are parts of a liberalization and privatization process that began in the early 1980s under the Conservative government of Prime Minister Margaret Thatcher. At that time, the government set out to roll back the reach of government in the private sector, focusing its efforts on the deregulation and privatization of key industries, such as airlines, railroads, telecommunications, and energy, which had long been under government control and/or ownership. In the government's view, the introduction of competition and free-market incentives in these industries would help to improve efficiency, provide better quality of service to consumers, and reduce associated operating costs.[24]

Utility Deregulation. The United Kingdom, which began the energy deregulation process with the passage of major legislation in the form of the Electricity Acts of 1983 and 1989, has been a leader among the industrialized nations, most of which have yet to implement energy restructuring to as great an extent. Deregulation of the UK's electric utility industry was phased in gradually over the course of a decade, beginning in 1990 with the introduction of competition in, and privatization of, the electricity generation and marketing businesses, and the introduction of supplier choice for large industrial firms. In 1994, the electricity market was deregulated for small industrial and commercial industries. The deregulation of the electric utility industry was completed in 1998, when retail-level deregulation was introduced nationwide. Distribution now occurs through twelve private, regional distribution companies, which also jointly own the country's regulated transmission grid.[25]

Since the late 1980s, the liberalization of the energy industries has been a primary objective of the United Kingdom's energy policy, which aims to provide a range of cost-effective energy choices to all classes of consumers. In addition to its domestic policy actions in this regard, the British government is also a strong advocate of energy liberalization throughout the European Union; in its view, the liberalization of networked energy systems across Europe will improve the overall security, flexibility, and efficiency of European energy systems and is likely to provide a wider range of energy choices and business opportunities for British consumers and industry.[26]

The deregulation of the United Kingdom's energy industries has realized some significant benefits. For example, deregulation has resulted in a net reduction of electricity prices in the UK. Between 1990 and 1997, average annual domestic prices for gas and electricity fell in real terms by 11% and 9%, respectively; over the same period, real industrial prices fell by 46% for gas and 21% for electricity. However, there has been a great deal of controversy surrounding the equity of the reforms, since many observers feel that large industrial consumers and industry executives have benefited at the expense of tax payers, smaller consumers, and electricity industry employees.[27]

Many of the initial efficiency gains brought about through deregulation were realized by large-scale layoffs; moreover, many analysts believe that the state-owned electricity assets were sold well below their full value, depriving the treasury of significant revenues. The issue of stranded assets, particularly in the nuclear power sector, has also proven difficult to resolve. Since only the most advanced nuclear facilities were privatized successfully, questions still linger regarding the fate of older plants and plants under construction which were unable to compete in a deregulated environment. To sustain the industry during the privatization process and to address the issue of stranded costs, the government ordered regional distribution companies to purchase specified quantities of nuclear-generated electricity. In 1990, a levy of 10% of total electricity revenue was implemented to reimburse the distribution companies for the purchase of nuclear and renewably-generated electricity at higher than market rates. Thus, a portion of the nuclear industry's stranded costs was passed on to electricity consumers through this non-fossil fuel obligation (discussed in more detail below).[28] The non-fossil fuel obligation still provides a subsidy of approximately $1 billion annually to the nuclear industry.[29]

The deregulation of the UK's natural gas industry in conjunction with electricity deregulation has had significant environmental benefits. The restructuring of the energy industries created an environment that strongly encouraged electricity generators to switch from coal to natural gas as the fuel of choice. Until the mid-1980s, electricity generators had been required to purchase set quantities of high-cost domestic coal. While coal had accounted for 66% of fuel use at UK electric utilities in 1988, by 1995 that percentage had fallen to 48%, due principally to substitution of natural gas facilitated by deregulation. Over roughly the same period, employment in Britain's coal industry fell from nearly 184,000 to 11,000. The substitution of gas for coal also helped the United Kingdom to reduce its greenhouse gas emissions and to comply with a 1988 European Community directive requiring a 60% reduction in sulfur dioxide emissions by 2003.[30]

Climate Change. Another energy policy goal of the United Kingdom is to meet its commitment under the United Nations Framework Convention on Climate Change to reduce its emissions of greenhouse gas emissions to 1990 levels by the year 2000. Due in large measure to the large-scale substitution of gas for coal in the electric utility sector, the UK's carbon dioxide emissions are likely to be 4-8% below 1990 levels by 2000. With respect to other greenhouse gases, the U.K.'s methane and nitrous oxide emissions are expected to be 22% and 62% lower, respectively, than 1990 levels.[31]

In 1997, at the Third Conference of the Parties to the Framework Convention on Climate Change, in Kyoto, the British government and the European Union (EU) accepted a new greenhouse gas emissions reduction target of 8% below 1990 levels within the period 2008-2012. Subsequently, the environment ministers of the EU adopted a Community Strategy on Climate Change, specifying individual EU countries' respective greenhouse gas reduction targets. Under this plan, some EU Member States will be allowed to increase their emissions over the next decade (e.g., Greece: +25%, and Spain: +15%), while other will have to reduce their emissions drastically (e.g., Germany: -21%, and Luxembourg: -28%). Under the EU's Community Strategy, the United Kingdom has agreed to a reduction target of 12.5%.[32] The UK's Minister for Science, Energy, and Industry, John Battle, acknowledged that "achieving this kind of target…is probably going to take some radical change in the way we regard energy and its use."[33] Mr. Battle acknowledged that meeting the government's energy and environmental goals in this regard will require the development and deployment of new energy technologies, particularly offshore wind energy and bio-energy crops.[34]

An important tool in the United Kingdom's efforts to reduce its overall greenhouse gas emissions is the Non-Fossil Fuel Obligation (NFFO). The NFFO, a statute imposed by the British government under the Electricity Act of 1989, empowers the Secretary of State to require that the UK's twelve regional electricity companies, which collectively form the national distribution network, secure a specified amount of generating capacity from non-fossil fuels (including nuclear and renewable energy sources) and permits a levy on electricity consumers to meet the additional costs involved. Already, 248 renewable energy projects are up and running as a result of the NFFO in England and Wales, or its equivalents: the Scottish Renewables Obligation (SRO) and the Northern Ireland NFFO. These projects cover a range of energy sources, including wind, hydro and waste.

The NFFO has been used to stimulate the market for renewable energy and to drive renewable technologies to become more competitive with conventional fossil fuel technologies. The NFFO is put out to competitive bid, aiming to place steady, downward pressure on the necessary subsidy for renewable energy. Contracts are placed by the Non-Fossil Purchasing Agency on behalf of regional electricity companies and offer long-term (up to 15 years) guaranteed purchasing arrangements designed to provide a stable framework for renewables projects. In 1990, when the first NFFO tender was made, successful wind energy projects produced electricity at approximately 14.7 cents/kWh; as of 1999, NFFO wind energy projects are producing at 4.85 cents/kWh—

just over one tenth of one cent higher than the 4.7 cent average selling price of the UK's electricity pool.[35]

Through the NFFO and R&D tax credits to energy technology producers, and through modest direct support for renewable energy R&D, the government aims to reduce significantly the UK's emissions of greenhouse gases. The government's target is to reduce emissions by 20% from their 1990 levels by 2010—a goal that greatly exceeds the UK's commitment to a 12.5% reduction under the Kyoto Protocol. The task will be exceedingly difficult, given the low levels of support for energy R&D that have persisted in the UK over the past decade, and considering that several of the renewable energy projects commissioned under NFFO have experienced substantial delays in the siting and licensing process. Although 650 MW of emissions-free electricity generating capacity has been commissioned under the program, a large fraction of that capacity must clear significant hurdles before coming online.[36]

Energy Security. In general, the British government relies on market mechanisms to ensure that energy supply security is maintained. Yet the potential costs that a supply interruption could impose on the economy, as the oil shocks of the 1970s did, have prompted the government to take a more active role in energy security matters. In its 1997 Energy Report, for example, the government called for a number of actions to improve the country's energy security including the completion of energy liberalization and the broader development of renewable energy sources as a means of greater energy self-sufficiency.[37]

Diversity is a key dimension of energy security in the United Kingdom. Although the government promotes competitive markets as a means of ensuring flexibility of response and innovation in the country's energy supplies and systems, diversity also means having both a wide range of fossil fuels and technologies, and alternatives to fossil fuels. Improving the UK's energy diversity is especially important considering the country's relatively few international connections for gas and electricity, and its high level of dependency on hydrocarbon resources from the Middle East.

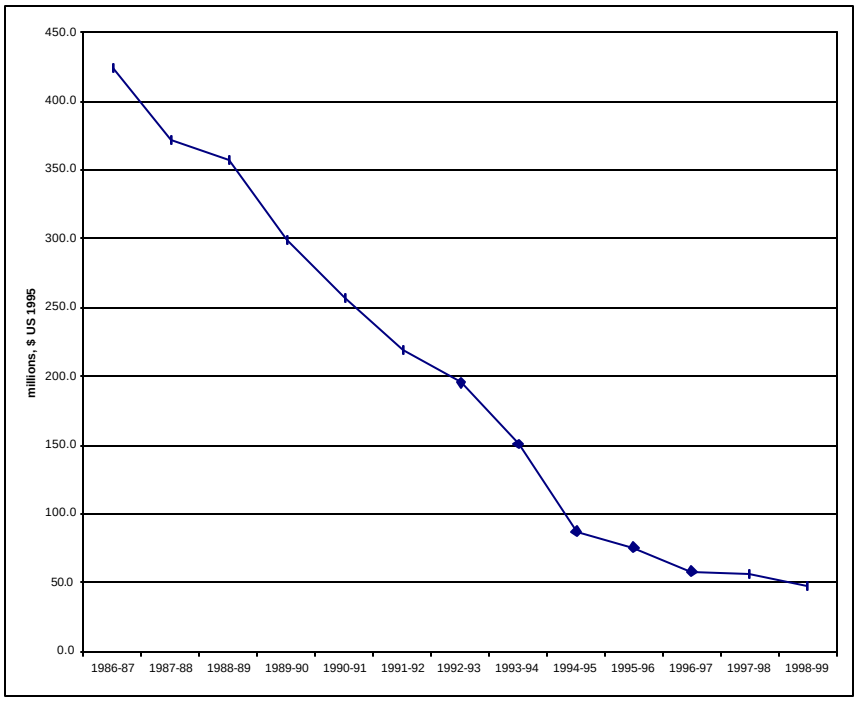
There has been growing concern within the government in recent years concerning the rapidly rising use of natural gas for electricity generation. Current estimates suggest that the UK may rely on imports (mainly from Russia and Algeria) for between 55% and 90% of its gas supplies by 2020. In order to forestall such developments, the government has acted to brake the rising dependence on gas by imposing a policy of stricter consents—amounting to a near moratorium—on the construction of new gas-fired power plants for the short-term, an action criticized by some observers as geared principally at preserving domestic coal industry jobs. This policy, in conjunction with the government's clean coal technology program, aim to encourage the use of domestic coal in high-efficiency combined heat and power projects viewed as furthering two energy policy goals, energy security and sustainability, simultaneously.[38]

In short, the government's policy with regard to energy security has three main components. First, the promotion of competition in energy markets is viewed as having the largest potential for ensuring security by creating flexibility, innovation, and diversity among suppliers using the price signal. Second, selective support for energy R&D, for instance in the clean coal and renewable technology areas, is viewed as playing a role in energy security and diversity, despite the fact that public support for energy R&D has declined by more than 90% since 1989. Finally, policy interventions in the market, through the use of regulatory and fiscal instruments such as the NFFO, and the stricter consents policy for natural gas-fired generating capacity, are also a key part of the government's energy security strategy.[39]

Energy R&D

Figure 6 shows the British government's recent investments in energy R&D. The decline in energy R&D support between 1996 and 1998 is consistent with the broader trend of the past decade, during which the U.K. public energy R&D expenditures have fallen by more than 90%.

Figure 6. Total Government Energy R&D Expenditures 1986-1999[40]



In recent years, government investments in energy R&D have been small and growing smaller--amounting to less than 1% of total civilian R&D expenditures in 1997. Energy R&D constitutes a sharply declining share of a declining overall civil R&D budget. Government funding for energy R&D now focuses to some extent on efforts to finalize development of technologies that are thought to have commercial promise, but that are not yet ready for introduction to the market. Primarily, however, the government R&D program emphasizes industry and international collaboration, and the removal of barriers to the commercialization and deployment of new technologies developed by the private sector, rather than on the direct sponsorship of energy R&D. With the exception of nuclear fusion, those energy R&D programs still receiving government support tend to emphasize technologies and projects that are likely to realize short-term returns.[41]

For example, the United Kingdom's cleaner coal technology R&D program, funded at approximately $5 million in 1998, aims mainly to position UK industry to exploit the growing world market for clean coal technologies and expertise. The UK's small

remaining public oil and gas research program focuses mainly on offshore geology and offshore supplies and services R&D.[42]

While the government previously funded nearly all renewable energy R&D in the UK, its investments in this area have steadily declined; the government now heavily leverages industry funding with its own R&D investments (in a ratio of approximately $2.5 to $1) and relies primarily on the non-fossil fuel obligation mechanism as a means of stimulating private sector improvements in renewable energy technologies.[43]

The government has also withdrawn its support for nuclear fission R&D, leaving this work to the privatized nuclear generating companies. The majority of government resources in the nuclear fission area ($352 million in 1998) are devoted to nuclear decommissioning and radioactive waste management. Funding for fusion research, which supports both the Joint European Torus Project and a domestic fusion program, has fared better than all other public energy R&D programs, with a funding increase of 40%--to $23million--between 1997 and 1998.[44]

Energy R&D Programs

Government-sponsored energy R&D programs in the UK have been drastically downsized or eliminated outright over the past decade. This section provides detailed descriptions of the government's remaining energy-related investments and activities, which collectively added up to approximately $478 million in 1998. While this figure may suggest, at face value, that the health of the UK's energy R&D enterprise is may not be as dire as claimed elsewhere in this report, it is important to note that the vast majority of these funds are not directed to energy R&D, even if they are classified as such. Nearly 90% ($418 million) of these funds is devoted to nuclear decommissioning and radioactive waste management programs, while many of the resources in the remaining programs areas (energy efficiency, fossil energy, and renewable energy) are directed toward energy technology demonstration and deployment activities. In short, with regard to energy R&D, few resources are expended on the "front end" of the innovation process, consisting of the basic and applied research foundations for novel energy technologies, while the majority of the available funds are used to spur the commercial viability of technologies already in the development process.

<u>Energy Efficiency</u> *$20 million [£ 15 million] (1998)*[45]

The government's investment in energy efficiency is consolidated within the Energy Efficiency Best Practice Programme (EEBPP), administered by the Department of the Environment, Transport, and the Regions. The overall objective of EEBPP is to stimulate annual energy savings in excess of $1 billion (equivalent to an estimated carbon emissions reduction of 5Mt/year) thereby improving industrial competitiveness and reducing environmental impact. The program promotes the adoption of energy-efficient technologies and techniques across the industrial, commercial and public sectors. One of

the program's primary activities is its collection of benchmark information on the energy use of selected UK industries. EEBPP studies the practices of the most efficient companies and shares its findings with all companies in each selected industry. A few years later, the study is repeated and the results are compared with those of the previous survey. The results typically show a shift toward more efficient practice.[46]

Currently, the EEBPP focuses its R&D efforts on the industrial and buildings sectors. The industrial energy efficiency R&D program, funded at $1.2 million in 1998, provides design advice and information on energy efficient equipment, such as motors and drives, and works with energy-intensive industries such as the chemical industry, to reduce energy consumption.[47] In recent years, the program's small R&D effort in the buildings area, which focuses on both the commercial and residential sectors, has been scaled down significantly, from just over $700,000 in 1996 to approximately $200,000 in 1998.[48]

The program also co-funds projects with European Union energy efficiency programs including the EU's best practice SAVE program, the research-oriented JOULE program, and applied technology THERMIE program. In addition to supporting these European Union R&D programs, EEBPP sets energy performance benchmarks, identifies important knowledge gaps, and provides information and advice to industry and government. The EEBPP program is currently phasing out its funding for ceramics research, since the government has deemed rate of return on its investment in this area of energy efficiency investment to be low compared with the returns on its investments in other industrial areas.[49]

New and Renewable Energy Sources *$20 million [£ 15 million] (1998)*[50]

Renewable energy currently accounts for 2% of the UK's electricity consumption. The government aims to increase renewables' share to 5% by 2003 and 10% by 2010. To achieve these targets it will apply a variety of measures, including the removal of barriers to entry for renewable energy technologies, for instance by separating the electricity generation and distribution businesses and creating a new wholesale electricity trading regime. The government will also use market stimulation measures such as the provision of guaranteed markets for non-fossil fuel generators (via the Non-Fossil Fuel Obligation), and direct support for renewable energy technology R&D.

The government gives priority to support for renewables R&D projects in technology areas that are likely to have the greatest impact, in the short term, in both domestic and export technology markets. Currently, technologies considered closest to being competitive in the UK or abroad, in the government's estimation, include waste-to-energy and biomass electricity generation, landfill gas, onshore wind, and passive solar technologies. Additional technologies that are being considered both for their export potential and for their potential contributions to the UK's 2010 target of 10% renewables include fuel cells, photovoltaics, offshore wind, and energy crops. Research supported by this program aims to make cost-reducing improvements that will enable the commercial deployment of renewable energy systems on a significant scale.

The government funds renewable energy R&D on a cost-share basis with UK companies and seeks to leverage its resources with those of EU energy R&D programs such as SAVE and THERMIE. In addition, Britain's Engineering and Physical Sciences Research Council has launched an expanded $5 million/year fundamental R&D program focusing on renewable energy. [51] Current projects sponsored by the Council focus on the enhanced use of solar energy systems in urban buildings, the improvement of power conversion efficiency in commercial wind turbines, and on the development of planning tools to assess offshore wind potential in the UK.[52]

Fossil Energy *$10 million [£ 7.5 million](1998)*[53]

The British government's investment in fossil energy R&D consists mainly of activities in three areas: clean coal technology development, offshore geology, and hydrocarbon recovery. Each of these programs is described below.

The Cleaner Coal Technology program formerly supported technology R&D, but its main emphasis now is the promotion and worldwide commercial deployment of UK-developed clean coal technologies, with emphasis particularly on developing country markets. The Program's budget has declined sharply over the past decade, to a level of $5 million in 1998. Through the Cleaner Coal Technology program, the government provides support to UK industry to secure funding from European Union programs to help develop UK-based clean coal technology manufacturing and service industries. In addition it provides support to UK industry in developing collaboration with the US Department of Energy's Clean Coal Technology Demonstration Program and related R&D program, and with US industry. [54]

Through the Department of Trade and Industry, the government also funds two programs in support of its regulatory activities in the oil and gas field. The Hydrocarbons Additional Recovery Programme (HARP) provides technical advice and research concerning the exploration and production of oil and gas on the UK continental shelf. The Offshore Geology Programme provides support for independent geological analyses of the UK continental shelf, and the extraction of cores and cuttings from hydrocarbon wells. These government-sponsored oil and gas programs were funded at a level of approximately $4 million in 1998.[55]

Fission Energy *$4 million [£ 3 million] (1998)*

The UK government has largely withdrawn its support for nuclear fission R&D, leaving the sponsorship of research to the private sector. The remaining research program sponsored by the government focuses on nuclear safety and accountability. That said, DTI provides a significant amount of non-R&D funding ($228 million in 1998) for a decommissioning, radioactive waste management, and fuel reprocessing program focusing on sites owned or operated by UK Atomic Energy Authority (UKAEA) and

British Nuclear Fuels. UKAEA manages the Decommissioning and Radioactive Waste Management Operations Programme (DRAWMOPS) for DTI. UKAEA owns and is legally responsible for the nuclear sites, the facilities being decommissioned and the associated wastes. Five sites are currently in the decommissioning process. The 1998 estimate of the total DRAWMOPS liabilities is about $10 billion. The planned program will extend over at least 100 years, the aim being to ensure that the liabilities are managed and dealt with in safe and environmentally responsible way while minimizing the associated costs.[56]

Fusion Energy *$23 million [£ 17 million] (1998)*

The UK's fusion energy program is funded through the Department of Trade and Industry and operated by UKAEA. The program funds UKAEA's contribution as host to the Joint European Torus (JET) and the UK national program that is part of the EU's fusion research program.[57] The UK national program focuses on the development and construction of a Mega Amp Spherical Tokamak reactor for magnetic confinement of high-temperature plasmas. The UK's fusion program resources are split roughly equally between the national and JET activities.[58]

Energy Assistance to Developing Countries *$4.6 million [£3.2 million](1996)*

The Department for International Development provides some technical assistance to developing countries in the energy and power areas. Funding aims to promote better access to energy services by encouraging restructuring of the power sector to reduce waste of both energy and financial resources. The program also encourages the use of renewable sources of energy (including hydropower) in developing countries by providing funding for feasibility analyses of renewable energy projects and for the development of local capacity to operate and maintain energy systems. The Department for International Development coordinates its efforts in the energy area with those of the European Union and the World Bank. A major objective of its collaboration with developing countries in the energy area is to reduce the environmental impacts associated with energy use, particularly emissions of carbon dioxide and other greenhouse gases.[59]

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[1] Central Intelligence Agency, *World Factbook 1999* http://www.cia.gov/cia/publications/factbook/index.html

[2] Central Intelligence Agency, *World Factbook 1999* http://www.cia.gov/cia/publications/factbook/index.html

[3] This figure represents the 1996 total of business enterprise R&D ($13.5 billion) and government funding of R&D ($8.8 billion), as reported in Department of Trade and Industry/Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (London: The Stationery Office Limited, 1998), pp. 13, 28.

[4] This figure represents the 1998 total government funding of energy R&D in the following civil departments: Department of Trade and Industry (fission energy R&D: $4 million; fusion energy R&D: $23 million; non-nuclear energy R&D: $27 million), Department of Environment, Transport, and the Regions

(energy efficiency R&D: $20 million). It does not include funding for the United Kingdom Atomic Energy Agency's Decommissioning and Radioactive Waste Management Operations Programme (DRAWMOPS). These figures are reported in Department of Trade and Industry/Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (London: The Stationery Office Limited, 1998), pp. 93, 99, 101.

[5] See Daniel Yergin and Joseph Stanislaw, *The Commanding Heights* (New York: Simon and Schuster, 1998).

[6] Department of Trade and Industry, Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (July 1998), p.71.

[7] The United Kingdom's ratio of industrial R&D to gross domestic product fell from 1.61% to 1.47% over the period. Reported in Economic and Social Research Council, "Promoting R&D Through Fiscal Incentives: An Assessment of the Arguments," http://www.ifs.org.uk/research/corporate/R_AND_D_CREDIT.HTM

[8] Department of Trade and Industry, Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (July 1998), p.71.

[9] Department of Trade and Industry, Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (July 1998), p. 36.

[10] HM Treasury and Department of Trade and Industry, *Innovating for the Future: Investing in R&D*, Consultation Document (March 1998).

[11] HM Treasury and Department of Trade and Industry, *Innovating for the Future: Investing in R&D*, Consultation Document (March 1998).

[12] HM Treasury and Department of Trade and Industry, *Innovating for the Future: Investing in R&D (A Consultation Document)*, March 1998, Chapter 2.

[13] HM Treasury and Department of Trade and Industry, *Innovating for the Future: Investing in R&D*, Consultation Document (March 1998).

[14] HM Treasury and Department of Trade and Industry, *Innovating for the Future: Investing in R&D (A Consultation Document)*, March 1998, Introduction.

[15] Department of Trade and Industry, "Allocation of the Science Budget 1999-00 to 2001-02," http://www.dti.gov.uk/ost/allosb9902/ALLBOOK2.html

[16] Department of trade and Industry/Office of Science and Technology, *Our Competitive Future: Building the Knowledge Driven Economy*, (London: The Stationery Office Limited, 1998).

[17] Economic and Social Research Council, "Innovation Update: The Role of Scientists and Engineers in Technological Change."

[18] Energy Information Administration, "United Kingdom: Country Analysis Brief," http://www.eia.doe.gov/emeu/cabs/northsea.html

[19] Energy Information Administration, "United Kingdom: Country Analysis Brief," http://www.eia.doe.gov/emeu/cabs/northsea.html

[20] Department of Trade and Industry, *Conclusions of The Review of Energy Sources for Power Generation and Government Response to Fourth and Fifth Reports of Trade and Industry Committee*, p. 17. http://www.dti.gov.uk/public/frame1.html

[21] Energy Information Administration, *Electricity Reform Abroad and U.S. Investment*, DOE/EIA-0616 (October 1997), p. 32.

[22] Energy Information Administration, *Electricity Reform Abroad and U.S. Investment*, DOE/EIA-0616 (October 1997), pp.29-30.

[23] Personal communication with Jonathan Temple, Science and Technology Liaison, Embassy of the United Kingdom, Washington, DC.

[24] U.S. Department of Energy, Energy Information Administration, "Electricity Restructuring and Privatization in the United Kingdom," *Electricity Reform Abroad and U.S. Investment* (Washington, DC: U.S. Government Printing Office 1997, pp.15-17.

[25] John Chesshire, "UK Electricity Supply Under Public Ownership," in John Surrey (ed.), *The British Electricity Privatization Experiment, Privatization: The Record, The Issues, The Lessons* (London: Earthscan, 1996), p. 19; Energy Information Administration, *Electricity Reform Abroad and U.S. Investment* DOE/EIA-0616 (October 1997), pp. 13-38.

[26] http://www.dti.gov.uk/public/frame1.html

[27] Department of Trade and Industry, "Regulating Energy Markets," http://www.dti.gov.uk/COMMS/dtiexweb/pages/pg07d.htm

[28] U.S. Department of Energy, Energy Information Administration, "Electricity Restructuring and Privatization in the United Kingdom," *Electricity Reform Abroad and U.S. Investment* (Washington, DC: U.S. Government Printing Office 1997, pp.13-14.

[29] Catherine Mitchell, *Renewable Energy in the UK: Policies for the Future* (London: Council for the Protection of Rural England, 1998), as reported in Curtis Moore and Jack Ihle, "Renewable Energy Policy Outside the United States," Renewable Energy Policy Project Issue Brief No. 14 (October 1999), pp. 12-13.

[30] U.S. Department of Energy, Energy Information Administration, "Electricity Restructuring and Privatization in the United Kingdom," *Electricity Reform Abroad and U.S. Investment* (Washington, DC: U.S. Government Printing Office 1997, 30.

[31] International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom 1998 Review* (Paris: OECD, 1998), p. 29. According to U.S. Department of Energy projections, however, the United Kingdom is likely to re-attain and exceed its 1990 carbon dioxide emissions level by the first Kyoto Protocol reporting period of 2008-2012. See: Energy Information Administration, *International Energy Outlook 1999* (Washington, DC: U.S. Government Printing Office 1999), p. 151.

[32] European Council, "Community Strategy on Climate Change, Council Conclusions," (Brussels, 23 March 1998).

[33] Department of Trade and Industry, *Shaping Change* (London: The Stationery Office Limited, 1997), quoted in: International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom 1998 Review* (Paris: OECD, 1998), p. 29.

[34] Department of Trade and Industry, "John Battle Launches Bidding for Fifth Non-Fossil Fuel Obligation," Press Release, November 25, 1997, http://www.coi.gov.uk/coi/depts/GTI/coi5019d.ok

[35] Department of Trade and Industry, *New and Renewable Energy: Prospects for the 21st Century* (London: Department of Trade and Industry, 1999), p. 22.

[36] Conversation with Chris Naish, AEA Technology Environment/ETSU, 28 July 1999.

[37]White Paper, "Conclusions of the Review of Energy Sources for Power Generation," Presented to Parliament by the Secretary of State of Trade and Industry by Command of Her Majesty, October 1998, pp. 23-24.

[38] White Paper, "Conclusions of the Review of Energy Sources for Power Generation," Presented to Parliament by the Secretary of State of Trade and Industry by Command of Her Majesty, October 1998, pp. 23-28; Department of Trade and Industry, "The Government's Policy for Clean Coal Technologies," http://www.dti.gov.uk/ent/coal/cleaner_coal/html/back.html

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[40] Department of Trade and Industry, Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998*, Office of Science and Technology, http://www.dti.gov.uk/ost/SETstats98/

[41] International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom 1998 Review* (Paris: OECD, 1998), pp. 97-98.

[42] International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom, 1998 Review* (Paris: OECD, 1998), p. 98.

[43] International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom, 1998 Review* (Paris: OECD, 1998), pp. 100-101.

[44] International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom, 1998 Review* (Paris: OECD, 1998), pp. 98-99; Department of Trade and Industry, Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (July 1998), p. 101.

[45] Department of Environment, Transport, & the Regions, http://www.research.detr.gov.uk/strat1999.htm#1

[46] Alliance to Save Energy, *Update* (Spring 1999), p. 10.

[47] Energy Efficiency Best Practice Programme, http://www.energy-efficiency.gov.uk/index.htm

[48] International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom, 1998 Review* (Paris: OECD, 1998), pp. 100.

[49] Department of Environment, Transport, & the Regions, http://www.research.detr.gov.uk/strat1999.htm#1

[50] This figure includes the renewable energy R&D budgets of the Department of Trade and Industry ($15 million) and the Engineering and Physical Sciences Research Council ($5 million).

[51] Department of Trade and Industry, *New and Renewable Energy: Prospects for the 21st Century* (London: Department of Trade and Industry, 1999), pp. 27-29, 68.
[52] Engineering and Physical Sciences Research Council, http://www.epsrc.ac.uk/epsrcgrants/portfolio.asp
[53] This figure includes the Department of Trade and Industry's budgets for clean coal technology ($5 million), offshore geology ($1.5 million), and the Hydrocarbons Additional Recovery Programme ($3.3 million).
[54] Department of Trade and Industry, http://www.dti.gov.uk/public/frame1.html
[55] Department of Trade and Industry, Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (July 1998), p. 101.
[56] Department of Trade and Industry, http://www.dti.gov.uk/drawmops/backgrnd.html
[57] Department of Trade and Industry, http://www.dti.gov.uk/drawmops/backgrnd.html
[58] International Energy Agency, *Energy Policies of IEA Countries: The United Kingdom, 1998 Review* (Paris: OECD, 1998), pp. 98-99; Department of Trade and Industry, Office of Science and Technology, *Science, Engineering, and Technology Statistics 1998* (July 1998), p. 99.
[59] Department for International Development, *Departmental Report 1998-1999* (London: The Stationery Office Limited, 1998), p. 37.