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Energy R&D in the European Union

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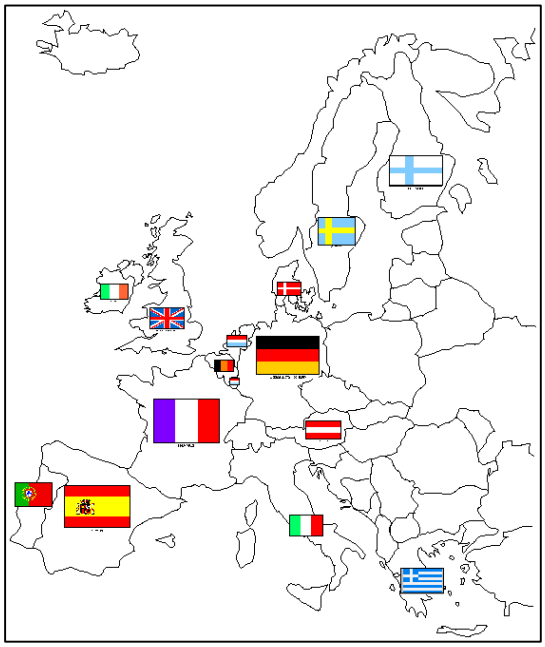
ABSTRACT: The European Union's total expenditures on research and development have grown rapidly since the mid-1980s. For example, in the period between the EU's First Framework Programme for Research and Technological Development (spanning the period 1984-1987) and the Fourth Framework Programme (1994-1998), R&D investments under the Framework Programme grew in real terms by more than 120%, from $6.4 billion to $14.5 billion. The budget for the Fifth Framework Programme (1998-2002) is projected to be approximately $15 billion. R&D investments in the health, biotechnology, information technology, and transportation areas have grown most markedly in recent years.

Energy R&D constitutes a major, yet declining, share of the total R&D expenditures of the European Union (EU). In the EU's first multi-year Framework Programme for Research and Technological Development ($1.7 billion between 1984-1987), energy R&D accounted for more than 50% of the budget; in the Fifth Framework Programme, only 14% of the budget is devoted to energy R&D ($2.1 billion between 1998-2002). Commitments to nuclear fission R&D have been the hardest hit, declining by more than 50% between 1988-1998. EU investments in non-nuclear energy R&D, particularly in energy efficiency and renewable energy programs, have fared best, having more than doubled since 1993 to become the largest element of the energy R&D portfolio. Growth in non-nuclear energy R&D program investments can be explained in part by the EU's increasing policy emphasis on the Framework Programme as a vehicle for technology commercialization and economic competitiveness, more so than as a platform for basic research. European energy efficiency and renewable energy technologies, to a greater extent than other energy technologies, are regarded as having great potential for commercialization and sale on the world market.

KEY WORDS: Energy R&D, European Union, Framework Programme, climate change, energy deregulation, energy security

European Union[i]



Population: 372,654,000 (1996 est.)[1]
GDP 1996: $7096.4 billion (ECU 6,765.0 billion[2])

Total R&D Effort 1998[ii]:

- $3 billion (ECU 3.3 billion)

R&D Expenditures as % Public Expenditures 1998:

- 3.6%[iii]

Energy R&D Effort 1998[3]:

- $472 million (ECU 474 million)

Chapter Overview

Summary of Analytical Findings
R&D in the European Union
Energy Policy
EU Energy R&D

[i] This report focuses exclusively on research and development programs administered at the Community level by the European Commission. It does not address any of the R&D programs funded and directed at the national or state/province level in any of the individual EU Member States. The R&D expenditures described here should be regarded as distinct from the R&D expenditures of individual EU Member States.
[ii] Community Research and Development Information Service (CORDIS), http://www.cordis.lu/en/src/i_004_en.htm. Includes only activities associated with the European Union's Fourth Framework Programme 1995-1998. The European Union primary vehicle for research sponsorship is the Framework Programme, a broad research umbrella including objectives and activities in many major socioeconomic areas. The Framework Programmes do not fund defense R&D. EU Framework Programmes span a period of four to five fiscal years and official EU publications express the cumulative, four-year budgets for the Programmes. Therefore, the figure for total EU R&D effort for 1998 provided here represents an average total annual R&D expenditure under the EU's Fourth Framework Programme.
[iii] This figure represents the portion of the General Budget of the European Communities devoted to R&D activities.

Summary of Analytical Findings

The European Union's (EU) research and development programs are distinct from, and complementary to, those of the fifteen individual EU Member States. Funding for the European Union's programs comes from the General Budget of the European Communities. In observance of the legal principle of subsidiarity, the EU programs are intended to focus on research activities that are too large and/or too complex for any single country to undertake alone. This report focuses exclusively on R&D programs and activities funded and administered at the supranational, EU level. It is also important to note that this report, unlike all others in this series of country studies, contains no information on trends in private sector energy R&D. Since private sector firms operating within the territory of the European Union are necessarily based within the borders of EU Member States, private sector R&D activities are addressed in the case studies of individual countries.

The European Union's total expenditures on research and development have grown rapidly since the mid-1980s. For example, in the period between the EU's First Framework Programme for research and technological development (spanning the period 1984-1987) and the Fourth Framework Programme (1994-1998), R&D investments under the Framework Programme grew in real terms by more than 120%, from $6.4 billion to $14.5 billion.[iv] The budget for the Fifth Framework Programme (1998-2002) is projected to be approximately $15 billion, covering a wide spectrum of research.

In addition to their role in promoting scientific leadership and economic competitiveness, EU-sponsored research and technology development activities play an important role in several other policy areas. For example, the Framework Programme model provides an important vehicle for European social and economic integration, encouraging the training, collaboration and exchange of researchers among EU countries, and facilitating joint research ventures among firms, universities, and research institutions throughout Europe. The Framework Programme also aims to provide leverage to existing precompetitive research and demonstration efforts in individual Member States.

There have been significant shifts over time in Framework Programme research priorities. Biotechnology and life sciences research have experienced the most consistent growth of all socioeconomic areas funded by the EU, both in real dollars and as a share of the Framework Programme budget, rising from approximately 3% to 12% of all EU-sponsored research between 1987 and 1998. In real terms, this represents a seven-fold increase, from $240 million to $1.7 billion. Funding for international scientific cooperation, training and mobility of researchers within the EU, and transportation research have emerged more recently as important areas of EU-sponsored research.

[iv] Note that prior to the Fourth Framework Programme, several major EU-sponsored research activities, such as the THERMIE energy technology demonstration program, operated independently of the Framework Programme. Thus, the major increases in Framework Programme budgets that occurred between the Third and Fourth Frameworks are, in large part, the result of a reclassification/incorporation of ongoing research activities rather than a substantial real increase in research funding and activity. Also, the expansion of the European Union to include Austria, Finland, and Sweden in 1996 also corresponded with increases in the EU research budget resulting from financial contributions from those countries.

Energy research has constituted the largest single area of investment in each of the European Union's five-year Frameworks since the earliest days of joint European Community research programs in the 1970s. The historical significance of energy as a joint European research area stems to a large degree from the impact of the first world oil shock of 1973 on Europe's economies. At that time, it became clear to Europeans that if their inefficient patterns of energy use were to persist, the economic and social foundations of an integrated Europe would be in danger of collapse. Consequently, energy research aimed at the development of new and more efficient technologies became a Community-wide priority and, in many respects, was regarded as a matter of survival. In 1978, for example, the Community spent nearly 70% of its research budget in the energy field.[4]

Since the 1970s, energy R&D has remained a mainstay of EU-sponsored research, although the urgency that originally spurred Community energy research in the crisis years of the 1970s-80s has since subsided. Today, while energy security still is a main objective of EU energy policy, economic competitiveness and environmental protection have also risen to become top energy policy priorities and energy R&D drivers. However, the overall share of the budget devoted to energy R&D has declined steadily, from nearly 50% in Framework Programme I ($1.7 billion between 1984 and 1987) to 14% in Framework Programme V ($2.1 billion between 1998 and2002).

In addition to its shrinking budget share, the energy R&D portfolio has changed significantly in its composition over the past decade. Non-nuclear energy R&D, encompassing programs focusing on fossil fuels, renewable energy, and energy efficiency, has grown over the past decade from the smallest to the largest program area of energy R&D investment, now surpassing both fission and fusion R&D. Due to the necessarily large scale and complexity of nuclear research, fission and fusion programs have always played a major role in EU-sponsored energy research, in keeping with the subsidiarity principle. The recent growth in EU-sponsored non-nuclear energy R&D reflects the rising significance of new, non-nuclear energy technologies, especially in the energy efficiency and renewables areas. The European Commission's 1995 White Paper, "An Energy Policy for the European Union," stressed the importance of these technologies to the attainment of major EU energy policy goals, including energy supply security and environmental protection.

Non-nuclear energy technologies are also viewed as important to the economic competitiveness of EU countries both for their potential to reduce European industry's energy input costs and for their export potential. In the Fourth Framework Programme, renewable energy grew to constitute the largest non-nuclear portion (14%) of the energy R&D budget, after declining sharply in the early 1990s. Energy efficiency has increased steadily over the past decade, from 3% of the total energy R&D budget in the Second Framework ($52 million) to 12% ($138 million) in the Fourth Framework.[5]

Energy deregulation and the EU-wide integration of national energy systems are also priority policy issues that are deemed to be central to the future economic

competitiveness of the European Union. The EU hopes that energy deregulation and integration will help to reduce Europe's high energy costs, thereby helping European industry to be more competitive in global markets. The EU is working to create trans-European energy networks, linking the networked energy systems (electricity and natural gas) of all fifteen Member States.

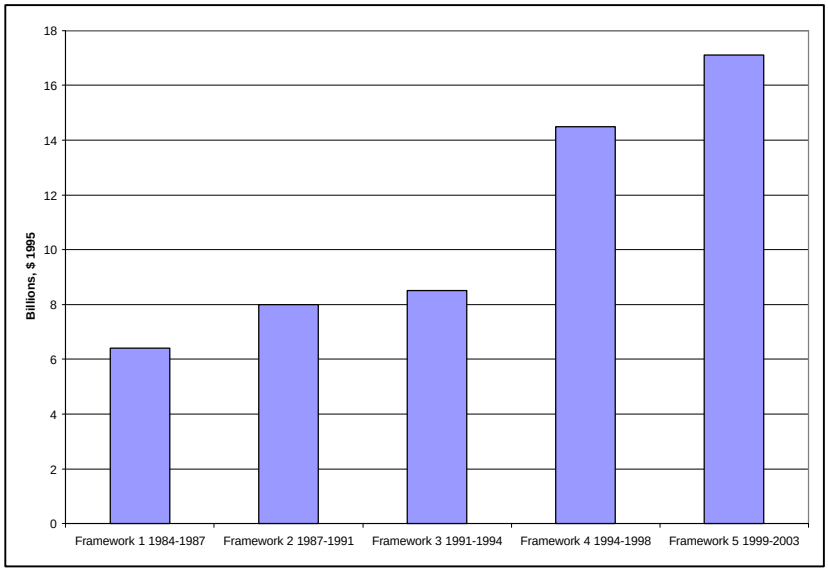
Under the 1997 Kyoto Protocol, the European Union committed itself to an 8% reduction in greenhouse gas emissions from 1990 levels by 2008-2012. Greenhouse gas emissions reduction and climate change mitigation now occupy a central position in EU energy policy. The increase in funding for renewable energy R&D in the Fourth Framework Programme aimed to propel the growth of renewable energy in Europe and to spur European economic competitiveness by helping European firms to capture a major portion of the growing worldwide market for renewable energy technologies.

EU research, in energy as in all other socioeconomic areas, focuses on promoting the overall economic competitiveness of the EU's Member States in the world market. With this in mind, a majority of the resources the EU devotes to energy is directed toward applied R&D, technology demonstrations, and pilot projects rather than to basic research or long-term technology development programs (with the exception of nuclear fusion). Even in the renewable energy area, for instance, efforts are focusing on the improvement and commercialization of existing technologies rather than on the development of fundamentally new technologies and systems.

R&D In The European Union

The European Union is a major sponsor of research and development activities in many socio-economic areas. The EU sponsors research in support of Community policies and priorities and, through its research funding, aims to advance European integration through the development of scientific and professional networks. The main vehicle of European Union research is the Framework Programme for Research and Technological Development, a multi-year plan drafted by the European Commission, and approved by the Council of Ministers and the European Parliament with input from the Member States and the Economic and Social Committee. Framework Programmes provide legal and administrative structure, scientific and technical objectives, and financial resources for EU-sponsored research. The Fifth Framework Programme began in 1999 and will run through 2002.

Figure 1. Framework Programme Budgets 1984-2003



The Programmes are financed from the General Budget of the European Union, consisting of Member States' financial contributions. Projects that receive research funding under the Framework Programme must involve participants from industry, universities, or research laboratories from at least two EU Member States. Projects are selected competitively on the basis of scientific merit and therefore those countries that contribute a larger share of the budget cannot automatically expect their research institutions to receive funding in proportion to their contributions.

Figure 2. EU Research Expenditures in Selected Socioeconomic Areas, 1987-1998[6]

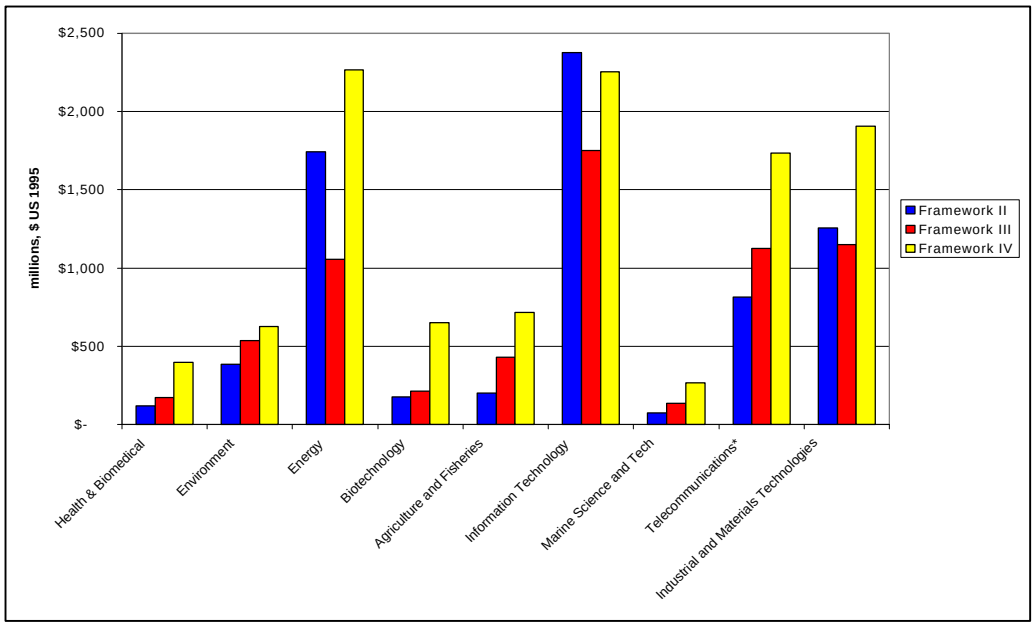


Figure 1 shows the EU's R&D expenditures in Framework Programmes I-V, covering the period 1987-1998. The EU Framework Programme budget has grown steadily since the Programme's inception in 1984. Between the first and fourth Framework Programmes, the total budget grew by more than 120% in real terms from $6.4 billion to $14.5 billion. The approved budget for the Fifth Framework Programme is $17.1 billion.[7]

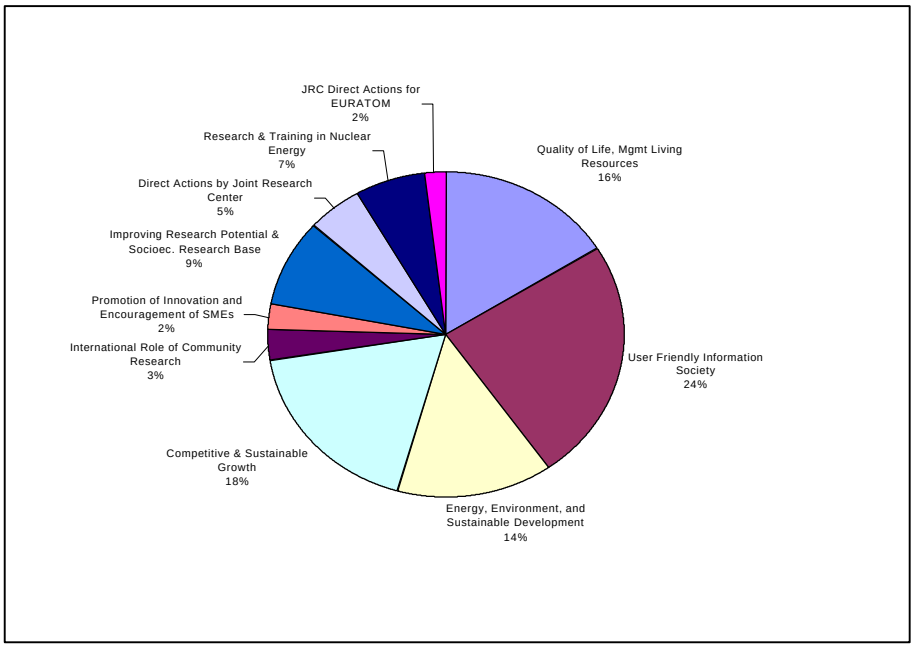
The EU's Framework Programmes cover a wide spectrum of research in the natural, engineering, and social sciences. Its major research areas (information and telecommunications, and materials research, biotechnology, energy, medical research, and the environment) have received consistent support for over a decade. At 87% of the budget, these areas constitute the lion's share of the Framework Programme's financial resources.[8]

That said, there have been significant shifts in emphasis among the priority areas over time, since their inception in 1984. In the First Framework Programme (1984-1987), for example, energy R&D accounted for close to 50% ($3.0 billion) of the overall budget, although its share has subsequently declined to approximately 14% ($2.1 billion) in the Fifth Framework. Note also, as Figure 2 shows, that the total Framework Programme expenditure on energy R&D appears to have grown sharply between the third and fourth Framework Programmes. The apparent jump in funding levels is actually due, in large part, to the incorporation of the $400 million Thermie energy technology demonstration program in the Fourth Framework Programme. Until then, Thermie had operated independently of the Framework Programme and consequently was not reflected in its budget. With the incorporation of Thermie, more than half of the EU's Framework Programme expenditures in the non-nuclear energy technology areas were devoted to demonstration activities, while the remainder was spent on the Joule energy R&D

program. This development clearly underscores the rising importance of technology demonstration and commercialization in the EU's technology R&D effort.

The trend in energy research reflects some important developments in Europe during the 1980s. First, prior to the adoption of the Framework Program organizational structure in 1984, energy R&D accounted for 50-70% of Community-sponsored R&D. Throughout the 1970s, energy occupied a central position in Community research because of the severe dislocations caused by the oil crises of 1973-74 and 1979-80. Following major reductions in energy intensity and the collapse of world oil prices by 1986, however, energy became a policy issue of relatively smaller significance than it had previously been. Second, the approval of the Single European Act in 1986 symbolized and cleared the way for accelerated European integration and the completion of a single European market. Consequently, European governments and industry began to place greater emphasis on the competitiveness of European industry and on the reduction of barriers within Europe that hindered industry's global economic competitiveness. More resources were to be devoted to the development of new industrial technologies and to common European codes and standards. Thus, in the budgets of the Second and Third Framework Programmes, fewer resources were devoted to energy R&D than had previously been the case, while industrial research accounted for more than 60% ($4.8 billion) of the R&D budget. While energy R&D expenditures rose modestly in the Fourth Framework Programme, the amount of new resources devoted to energy research, development, and demonstration is far more modest than Figure 2 seems to suggest.

Figure 3. Breakdown by Major Area of Proposed Budget, Fifth Framework Programme, 1998-2002[9]
(Total: 14.9 billion Euro)



In recent years, two areas that have grown most significantly as a share of the total Framework Programme budget are those of life sciences/biotechnology and environmental research, which now account, respectively for some 12% ($1.7 billion) and 8% ($1.2 billion) of the Fourth Framework Programme budget.[10] The increases in the life sciences and biotechnology areas reflect the significant scientific advances that have occurred in this area over the past two decades that have made it a high priority from both economic and human health perspectives. Similarly, the growth in environmental research (e.g., earth and marine sciences) highlights the growing extent to which environmental issues have become policy priorities across the European Union. The increases in EU funding in both of these socio-economic areas is also necessitated by the fact that addressing large, complex problems such as global climate change or the mapping of the human genome lie beyond the research capabilities and resources of any single country. However, in addition to "big science" projects in the life sciences, such as the Human Genome Project, the Framework Programme also sponsors research in several other commercially promising areas including bioremediation, molecular engineering, and biotechnological processes for agroindustry.[11]

The European Council formally adopted the Fifth Framework Programme in November 1998. Its specific or "thematic" research programmes are oriented to the achievement of the following four Community policy objectives: ensuring quality of life and living resources; creating a user-friendly information society; achieving competitive and sustainable growth; and preserving the regional and global ecosystems (see Figure 3).[12] The themes of the Fifth Framework Programme indicate a reorganization of European research that reflects the growing importance of research in the environmental and information technology areas. The new Programme will also place significant emphasis on the economic value-added of EU-sponsored research, by aiming to translate EU R&D investments into European products for the world market. The European Parliament and the Council recently agreed on a maximum overall budget limit of approximately $17.1 billion[v] for the Fifth Framework Programme [13]

EU funding is oriented toward research projects that demand transnational cooperation and the development of broad research networks. EU Framework Programme activities observe the legal principal of subsidiarity in funding research projects, supporting mainly projects that would be unlikely to receive private support and those that lie beyond the capabilities of individual governments. At the same time, however, a key aspect of the Framework Programme is its role as a "multiplier" of the efforts of European industry and of individual Member States. Although EU-sponsored research leaves technology commercialization to the private sector for the most part, the bulk of the Framework Programme budget is devoted to technology development, deployment, and demonstration, and to the promotion of R&D cooperation involving governments and the private sector rather than to basic research activities. The Framework Programme's stated

[v] Note: Purchasing power parity exchange rates are not yet available for the single European currency, the Euro, which was launched in January, 1999. The Euro/dollar exchange rate used here was calculated by averaging the daily Euro-dollar exchange rates for the first quarter (January 1-March 12) of calendar year 1999. Based on this calculation, the Euro/dollar rate is 0.8718. Daily rates can be found at http://www.jeico.com/cnc57ecu.html

goal of fostering a strong and integrated European economy helps to explain this orientation.[14]

An important rationale behind the EU's activities in the field of researcher training and mobility, in addition to augmenting Europe's overall scientific capabilities, is to build research networks specifically among European researchers. In 1995, for example, the European Commission found that European researchers more often formed stronger links with researchers and laboratories across the Atlantic than with those in neighboring countries. Thus, a major aim of EU support for basic research and researcher training is to consolidate and increase intra-European scientific capacity.[15]

In addition to the research infrastructures of the individual Member States, the EU has its own research complex, the Joint Research Centre (JRC). It includes eight specialized research facilities at five sites throughout Europe that receive research support directly from the General Budget of the European Union under the Framework Programme. Funding for the JRC accounts for 8% of the Fourth Framework Programme Budget; in 1996, the JRC's total budget was $286 million.[vi] Although the JRC was created to share, at the European level, the large investments needed to carry out research on nuclear energy, over time its tasks have developed into other areas in which a common European approach is necessary. JRC conducts research in the following areas: industrial materials (e.g., ceramics and composites), measurement and testing, environmental and earth science (e.g., remote sensing and atmospheric science), non-nuclear energy; targeted socio-economic research, nuclear fission safety (e.g., reactor safety, safety of fissile materials), and controlled thermonuclear fusion (participation in ITER activities).

In addition, the JRC plays an important policy support role. It conducts research that informs the development and implementation of European Union policies in the following areas: information and communications technologies (e.g., security and reliability of information systems); environment (e.g., control of chemicals, foodstuffs, and drugs); life sciences and technologies (e.g., remote sensing to monitor the common agricultural policy); targeted socio-economic research, and nuclear fission safety (accident prevention).[16]

[vi]This figure includes direct appropriations to the JRC from the Commission as well as resources provided by European Economic Area Countries (Iceland, Liechtenstein, and Norway), work for third parties, and other sources. See: European Commission, Directorate General for the Joint Research Center, *Annual Report 1996* EUR 17339 EN (Luxembourg: Office for Official Publications of the European Communities, 1997), p. 26.

Energy Policy

With a 44% share of energy consumption, oil continues to dominate Europe's fuel mix, as shown below in Figure 4. Moreover, more than 70% of the EU's oil is imported from Russia, the Persian Gulf region, and North Africa.[17] The vast majority of European oil consumption goes to the transportation sector. Natural gas is the fastest growing component of the fuel mix, spurred on by its desirable environmental properties and by the growth of the natural gas resource base over the past decade. Gas competes most directly with coal, which has lost substantial market share in recent years. While nuclear energy continues to play a major part in European energy, the industry's long-term future appears increasingly uncertain. Efforts to phase out nuclear power completely in Germany, for example, are ongoing, and enjoy the support of major political parties and segments of the public. In other EU countries such as France, however, nuclear power provides more than half of the electricity consumed. In the longer term, European energy integration and deregulation may pose an even more serious challenge than popular opposition has thus far to the future viability of the European nuclear power industry. Cheaper, less capital-intensive, and possibly less risky fuel sources like natural gas could undermine future investments in nuclear plants. Renewable energy plays a small but growing role in the European energy mix. As more countries impose carbon taxes and renewable portfolio standards, renewable energy is expected to gain a larger market share in upcoming years
(see Figure 5).

Figure 4. EU Total Energy Consumption, 1996 (61 Quads)

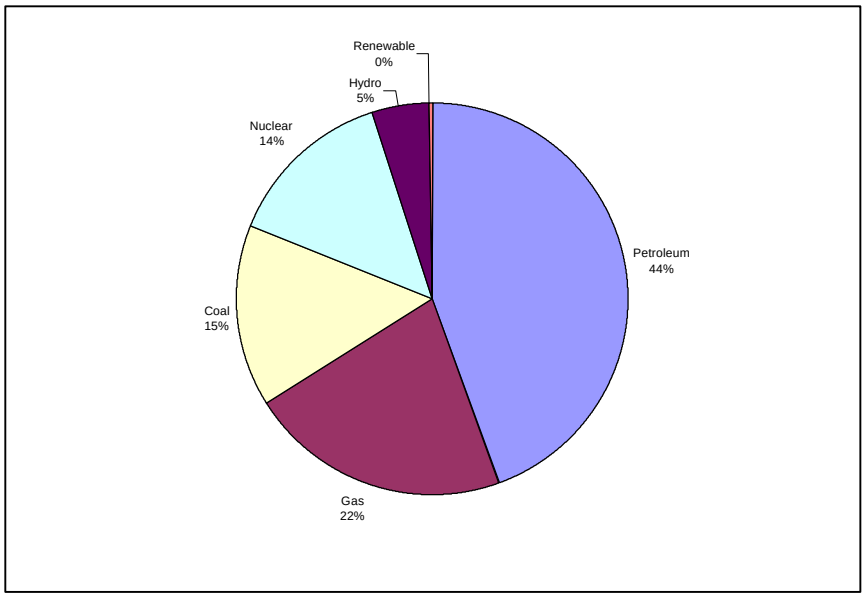


Table 1. European Union: Energy Overview 1996

Energy Import Dependence: 52%	Energy-Related Carbon Emissions: 878 million metric tons
Energy Consumption per Capita: 164 million BTU	Carbon Emissions per $1000 GDP: 0.12 metric tons
Energy Consumption per $1 GDP: 8100 BTU	Carbon Emissions per Capita: 2.3 metric tons
"Kyoto Commitment": 8% reduction in greenhouse gas emissions from 1990 levels by 2008-2012	

In December 1995, the European Commission issued the white paper, "An Energy Policy for the European Union."[18] In issuing the paper, the Commission established an official basis on which to build a common, community-wide energy policy. Even though two of the three treaties that form the legal foundation of the European Union (the European Coal and Steel Community Treaty of 1951 and the European Atomic Energy Community Treaty of 1957) are based on cooperation in the energy sector, the European Commission has not, until recently, moved to create a common EU energy policy.

In the Commission's view, a common energy policy will further economic integration within the EU and contribute to the realization of a single European market. According to the white paper, energy policy must form part of the general aims of the EU's economic policy, which focuses on market integration and deregulation, aiming to minimize its policy interventions. An EU energy policy would aim to enhance European economic competitiveness and supply security, and contribute to the achievement of the EU's broader policy goals relating to job creation and environmental protection.[19]

The language of the European Council Decision formally adopting the Fifth Framework Programme indicates even more clearly than previous official documents the growing importance of closer linkages between EU energy, trade, and R&D policies. Annex II of the Decision states, for example, that

> "[t]he need for energy equipment suppliers and operators to be competitive in the global market is vital for employment. Enormous potential will exist for global exploitation from several areas of the program, strengthening economic competitiveness and creating new jobs, such as in the water industry, renewable energy technologies, rational use of energy and reuse of resources, as well as technologies to improve energy efficiency and the water and/or energy industries."[20]

EU energy policy aims at once to address growing environmental concerns associated with the energy sector, such as global climate change, and to transform this growing concern for sustainability into opportunities for global economic and technological leadership. This overarching goal is supported by activities in three main energy policy areas (utility deregulation, energy security, and protection of the environment and

climate). These three areas, each of which is described below, represent the most significant pillars of EU energy policy.

Utility Deregulation: One of the most important energy and economic policy goals of the European Commission is the creation of a single, integrated European energy market. Currently, each of the EU's fifteen member states is at a different point on the path to the liberalization of its energy industries, and each state has a unique set of energy institutions and regulatory structures. The Commission aims to further each of its three main energy policy concerns—competitiveness, supply security, and environmental protection—through the creation of trans-European energy networks. A key action facilitating the development of these networks will be the Community-wide reduction of existing regulatory barriers and the introduction of competition in the energy industries, especially gas and electricity.[21] Other important developments include:

- Adoption in 1996 of a Directive for the Internal Market for Electricity. The Directive marks the first major legislative step toward the creation of an open and competitive European electricity market. Under this law, all Member States were required to open at least 25.37% of their electricity markets to competition as of February 1999.[22] This represents the overall share of electricity supply used by consumers larger than 40GWh. The opening of the European electricity market to competition is scheduled to move forward until 2003, at which point more than 80% will have been liberalized.[23] According to the European Commission, several countries are now ahead of schedule in liberalizing their electricity industries, such that by February 2000, more than 60% of European consumers will be able to select their power supplier. Complete liberalization of the generation sector became effective as of February 1999.[24]
- The Council of Ministers' adoption, in February 1998, of the European Union Common Position on rules for the internal market in natural gas. This action is a precursor to the adoption of future legislation regarding the liberalization of the European gas industry by the European Parliament.[25]

Fully liberalizing and integrating the EU's energy markets will be an exceptionally difficult task because of the major differences in attitudes and existing institutions among Member States. For example, the United Kingdom has been a leader with regard to energy market liberalization. Deregulation and privatization of the electricity industry began in 1989 and was completed in 1998, allowing all consumers now to choose their electricity providers. In France, on the other hand, the government has largely resisted pressures for deregulation. Some 95% of the country's electricity generation, transmission and distribution system remains in the control of a single state-owned firm, Electricite de France (EDF). Thus, the process of European energy integration is complicated by the challenges associated with reconciling the esoteric structures, traditions, and histories embodied in each Member State's energy system.[26]

The liberalization of Europe's energy markets is in keeping with the broader global trend of liberalization and deregulation of major industries (e.g., airlines, telecommunications) that began in the 1980s. There are, however, specific economic and legal reasons that liberalization of the energy industries is now a priority policy issue in the European

Union. For example, the Commission recognizes that many of the EU's industries are forced to compete in an increasingly integrated global marketplace, where lower-cost producers have distinct economic advantages.[27] Considering that European industries on average pays between 30% and 50% more for energy than those of the Americas or in parts of Asia, the introduction of competition to Europe's energy industries is intended to help European firms to compete globally by reducing their energy input costs.[28]

Energy Security: Ensuring energy supply security is a second key objective of EU energy policy. The EU is currently approaching 70% dependence on external sources of energy, and this trend appears likely to continue for the foreseeable future.[29] While the EU member states have participated in cooperative crisis management institutions, such as the International Energy Agency, since the 1970s, the Commission believes that these arrangements must be updated in the light of major changes in the political landscape that have occurred over the past decade. For example, the development of the common market and the expansion of the EU provide Europe with greater potential flexibility in responding to external supply interruptions. At the same time, the growth in global demand for oil and Europe's "inevitable and spectacular worsening of dependence on outside supplies" lends greater urgency to the need for Member States to coordinate their energy security efforts and to work together to reduce their collective energy vulnerabilities.[30]

Thus, the objectives of EU policy with regard to energy security are to ensure sufficient Community coordination during crises, to reduce the costs associated with such security measures, and to develop an effective EU-wide fuel stock management system. Two stages may be necessary to realize this goal: first, a revision of member states' compulsory oil stock obligations to improve readiness for future oil shocks, and second, the coordination of stock management measures ensuring their compatibility with the internal market. The further integration of Europe's energy markets, which will facilitate the freer movement of energy resources within the EU, is also regarded as an important element of EU energy security policy.[31]

The EU is also seeking to enhance its energy security through a variety of policy actions aimed at diversifying both Europe's internal fuel mix and its external sources of energy supply. The Commission considers all major fuel types (fossil, nuclear, renewable) and energy efficiency important elements of long-term energy security and is encouraging Member States to maintain a broad portfolio of energy supply options and to ensure that there is a broad internal energy resource base. For example:

- To capitalize on indigenous renewable energy resources, in 1991 the Commission set a target of 4000 MW of installed wind power capacity by the year 2000. Yet, as a result of improvements in wind technologies and new opportunities for renewable energy resulting from energy deregulation, the Commission's original target has already been surpassed. Installed wind capacity in the European Union already stands at 6,000 MW and is expected to reach 8,000 MW by the turn of the century.[32]
- The development of trans-European energy networks integrating the electricity and gas systems of all fifteen EU countries and several countries in Central and Eastern

Europe and the Mediterranean basin aims to diversify supply options beyond the EU's own borders. Cooperative gas pipeline projects between EU countries and Russia, Algeria, and other countries are being financed through a variety of EU instruments, including European Investment Bank loans and EU-sponsored programs such as PHARE and TACIS, which provide funding for feasibility studies and technical cooperation with third countries.[33]

- The EU is also fostering technical and policy cooperation with key supplier countries such as those of the Persian Gulf region as a means of maintaining good overall international relations and energy supply security.[34]

Protection of the Environment & Climate: The third major objective of EU energy policy is environmental protection. The Commission believes that the goals of greater economic competitiveness and environmental protection are not necessarily in conflict, and that policies that move industry to invest in new, cleaner, and less energy-intensive technologies (principally in the energy efficiency and renewable areas) will prove an advantage rather than a penalty to European firms in the long term. For example:

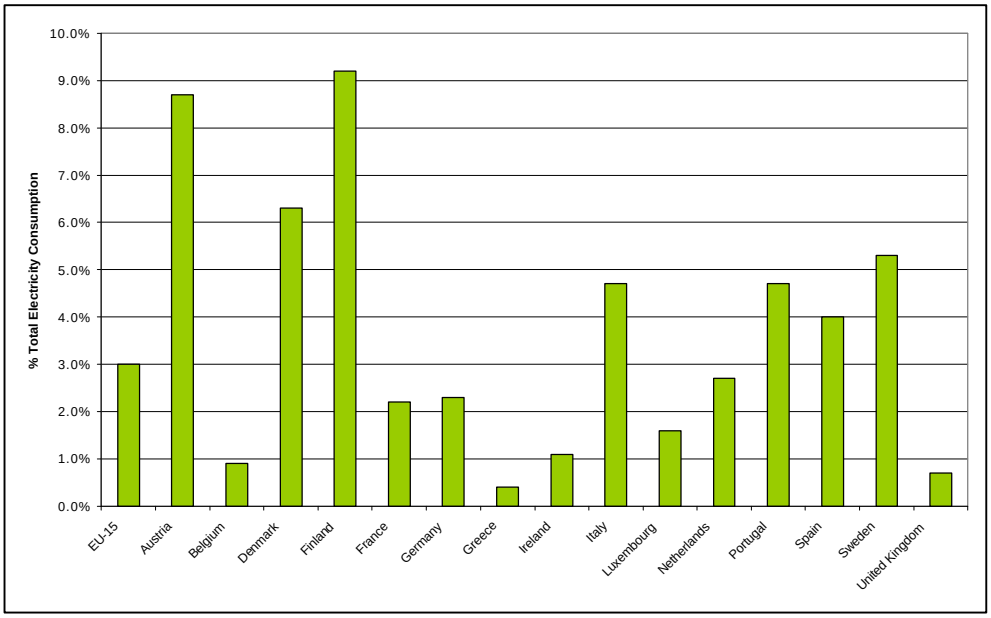
- The European Council Decision of January 25, 1999 adopting the Fifth Framework Programme specifically calls attention to the global economic opportunities associated with the development and deployment of new energy efficiency and renewable energy technologies. Moreover, the Programme includes funding to encourage innovation in energy technology and to assist European firms in moving them into the international market.[35]
- The European Union is a party to the Framework Convention on Climate Change and a signatory of the Kyoto Protocol. Among the industrialized countries, the EU has consistently played a leadership role in urging the adoption of actions based on the precautionary principal to address climate change. It was the EU's commitment at the Rio Earth summit in 1992 to stabilize its carbon dioxide emissions at the 1990 level by 2000 that persuaded other countries to follow suit. In fact, the EU may be the only industrialized region to live up to its carbon reduction commitment, aided in this to a large extent by the closing of inefficient coal-fired power plants in eastern Germany and intensive fuel switching (from coal to natural gas) in the UK's electricity sector. Similarly, in 1997, the EU took the lead at the Kyoto climate conference in proposing aggressive targets and timetables for industrialized countries' emissions reductions. In committing to an 8% emissions reduction from 1990 levels within the period 2008-2012, the EU adopted the most ambitious target in the industrialized world.[36]
- Following the December 1997 Kyoto climate change conference, the European Council issued a Community Strategy on Climate Change, specifying Member States' individual greenhouse gas reduction responsibilities in realizing the Kyoto commitment. Some Member States have committed themselves to steep emissions reductions (e.g., -28% for Luxembourg; -21% for Germany and Denmark), while, in the interest of economic development, Europe's less-developed economies have negotiated larger greenhouse gas emissions allowances under the EU agreement (e.g., +27% for Portugal; +25% for Greece). The ambitious greenhouse gas reductions targets aim to spur the adoption of energy efficiency technologies and best practices,

and to increase renewable energy sources' share in European energy supply, which currently stands at approximately 6%.[37]

- In 1996, the Commission proposed a Community-level carbon tax that would provide an EU-wide incentive for higher levels of energy efficiency, particularly in the industrial sector, and for the substitution of low- and non-carbon energy sources. The proposal has not yet been adopted.[38]

At the 1998 Buenos Aires climate conference, the EU's policy position with regard to the industrialized countries' actions to mitigate climate change has placed it at odds with other industrialized countries, particularly the United States. For example, the EU and the US positions have clashed in discussions of provisions of the Kyoto Protocol dealing with the use of international emissions trading and technical assistance for developing countries through an institution called the Clean Development Mechanism. While the United States favors the use of these institutional arrangements as primary means of achieving the Kyoto commitments, the EU maintains that the use of such arrangements must be supplemental to industrialized countries' domestic actions. In the EU's view, the industrialized countries have an obligation to reverse their emissions trends in real terms at home, and should not rely primarily on what they consider "paper credits"—emissions credits purchased from other countries whose emissions fall below their allowable limits.[39]

Figure 5. Green Electricity in the EU: Electricity Generated from Renewable Resources, (Excluding Hydroelectric Installation >10 MW), 1998[40]



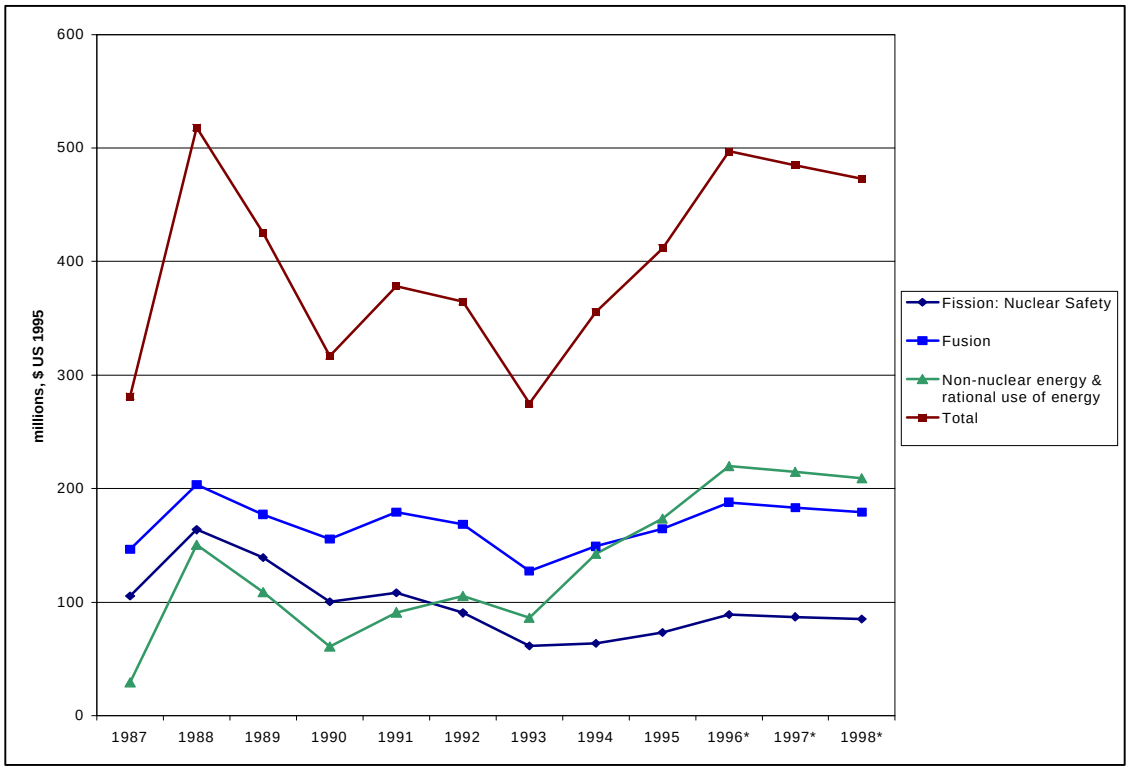
To reduce European greenhouse gas emissions, the Commission has proposed actions in key economic sectors. In the energy sector, for example, the EU aims to double the contribution of renewables (to 12%) and cogeneration (to 18%) by the year 2010. To

promote increased use of renewable energy, the Commission intends to adopt a proposal for a draft Council and Parliament Directive on common rules for supporting electricity generated from renewable sources. Among the provisions of the proposal will be a requirement that all Member States generate a minimum percentage of electricity from "green" sources. As Figure 5 shows, the amount of renewable energy produced and consumed in the EU varies sharply among Member States, ranging from 0.4% in Greece to 9.2% in Finland.[41] The broader use of renewables aims not only to reduce greenhouse gas emissions, but also to slow the growing dependence of imported fuels and to stimulate employment in new, high-tech companies.[42] In the transportation sector, the Commission has brokered a voluntary agreement with European car manufacturers to reduce passenger car emissions by some 90 million tonnes—an estimated 15% of the Kyoto target—over the next decade.[43] Individual companies in other industries, such as Germany's electronics giant AEG, have announced plans to reduce the average energy consumption of their home appliances by at least 25% between 1995 and 1999. Such initiatives are not uncommon and are strictly voluntary.[44]

EU Energy R&D

Although energy R&D now accounts for a smaller percentage of the overall Framework Programme budget, it continues to occupy a major position on the overall EU research portfolio. EU energy research has an increasingly large demonstration component. In fact, in the Fourth Framework Programme, demonstration activities account for some 55% of funded activities in the non-nuclear energy fields. This fact is indicative of the growing importance of the Framework Programme as a tool of European economic competitiveness as well as a vehicle for collaborative scientific research.[45] Also, as Figure 6 shows, non-nuclear energy, particularly energy efficiency and renewable energy technologies, has grown significantly in importance, surpassing both nuclear fission safety and fusion to become the largest single component of the energy R&D budget. This shift in priorities has been driven in part by internal energy and environmental policy objectives in the EU, as well as by the rising prospects for these technologies in the world market.

Figure 6. Framework Programme Energy R&D Expenditures 1984-1998[46]



Approximately $1 billion (approximately $250 million annually) will be invested in non-nuclear energy R&D over the life of the Fifth Framework Programme, which runs from 1998-2002. Among the major technological objectives in the energy area will be the development of large-scale electricity generation systems with reduced CO_2 emissions, and the development and demonstration of decentralized energy systems fueled by

biomass, wind, solar, and fuel cell technologies. Energy efficiency in the production, conversion, storage, and use of energy will also continue to be a central theme of the EU's energy R&D effort. Nuclear fission and fusion research is scheduled to receive approximately $1.3 billion (about $315 million annually) in the Fifth Framework Programme.[vii]

Under the Fourth Framework Programme (1994-1998), a $14 billion research effort, the European Union sponsored a wide variety of energy research and development projects. Approximately $2.3 billion was directed toward energy research. The major EU-sponsored energy R&D programs were the non-nuclear energy Joule-Thermie program, the nuclear fission safety program, and the controlled thermonuclear fusion program; these three programs together accounted for approximately 18% of the European Union's overall R&D budget between 1994-1998.[47]

Descriptions of major EU energy R&D program activities are provided below. This section includes summaries of R&D efforts under both the Fourth and Fifth Framework Programmes, since the transition between the two Programmes is still ongoing. The Fifth Framework Programme, adopted in January 1999, exhibits major changes from those that have preceded it in terms of organization and programmatic objectives. Changes in focus between the two Framework Programmes, as they relate to energy R&D, are discussed. In addition to its descriptions of Framework Programme energy R&D, this section also provides summaries of related EU-sponsored activities outside the Framework Programme.

Energy R&D in the Fifth Framework Programme, 1998-2002[48]

Under the Fifth Framework Programme, the projected budget for nuclear and non-nuclear energy research, development and demonstration activities is approximately $ 3.7 billion--approximately 20% of the overall Framework Programme budget of $18 billion.[viii] The organization of non-nuclear energy R&D activities, like those of other socioeconomic areas, have been restructured in the Fifth Framework Programme.

Whereas R&D were previously funded along the lines of traditional socioeconomic objectives such as energy, health, research will now be clustered around a series of four broad themes (quality of life and management of living resources; the user friendly information society; competitive and sustainable growth; and energy, environment and sustainable development) and three crosscutting themes (confirming the international role of Community research, promotion of innovation and encouragement of small- and medium-sized enterprise participation, and improving human research potential and the socio-economic knowledge base). The EU has reoriented its research along these

[vii] The figures presented here were calculated from the European Council's indicative breakdown of the amounts deemed necessary for R&D in the nuclear and non-nuclear energy areas, and in nuclear fission safety and safeguards. See: *Official Journal of the European Communities*: OJ L 64/62 13.3.1999; OJ L 64/145 12.3.1999; OJ L 64/157 12.3.1999.
[viii] See footnote v concerning Euro to US dollar conversion rates.

programmatic lines to align them more closely with EU policy objectives. For the purpose of this study, however, the Fifth Framework Programme energy R&D activities are discussed in conjunction with those of the Fourth Framework. Despite the recent reorganization of R&D activities, there is a high degree of continuity in the research programs. Describing the Fourth and Fifth Framework Programme activities together emphasizes the programmatic continuity rather than the organizational shifts in the conduct of European R&D.

Non-Nuclear Energy R&D In The Fourth Framework Programme, 1994-1998—The Joule/Thermie Programme ($239 Million/Year 1994-1998)[49]

The activities of the EU's Joule and Thermie programs constitute its non-nuclear energy R&D, and demonstration efforts, respectively . Budget figures presented for each of the five non-nuclear energy R&D program areas (RTD Strategy, efficiency, renewables, fossil, and technology dissemination) discussed below are estimated annual expenditures. They represent the maximum total expenditures allowable in the respective areas over the life span of the Fourth Framework Programme (1994-1998), divided by five to reflect an average annual expenditure for each technology program area.

Energy Efficiency[50] *($60 million/year, 1994-1998)*

Reducing energy consumption and stimulating market penetration of innovative efficient and clean technologies is a major priority of EU energy policy. Improving energy efficiency will play a major role in Community efforts to reduce dependency on external supply of energy products, and to lessen the environmental impacts of energy use. Under the Fifth Framework Programme, priority areas include the development and deployment of technologies for the transmission and distribution of energy; energy storage technologies on both small and large scales; improved efficiency of new and renewable energy sources; and the analysis of cost-effectiveness and efficiency, based on whole-life costs, of all energy sources. The annual budget for energy efficiency and renewable energy R&D collectively is estimated at $167 million between 1998 and 2002.

Efficiency in buildings. The buildings efficiency research program focuses on technology deployment and demonstration programs to validate and support the adoption of new energy efficient building equipment/materials and best practices in building design. For example, a major cost-shared buildings efficiency program in EU countries in the Mediterranean basin is working to integrate low-energy design and construction techniques, including solar water heaters and advanced materials, into new residential buildings. Thermie also provides support for the construction of solar, low-energy public buildings and residences in eleven European towns and cities. The buildings program does not fund the development of buildings energy technology R&D per se.

Industrial Energy Efficiency. Projects receiving support aim to reduce energy consumption and pollution associated with industrial processes, focusing on opportunities for material recycling and water resource conservation. Several projects sponsored under

the Joule programme focus on the capture and use of waste heat and gases from industrial processes for use in commercial/industrial heat pumps, district heating, and refrigerators. Research projects also aim to create new design methodologies using life cycle assessment and operations research to improve the energy efficiency of industrial processes and systems for new and existing industrial plants.

Energy conversion and fuel cells. Efforts seek to increase the efficiency of primary energy conversion by improving the performance and reducing the cost of fuel cells. Research is being conducted on low temperature solid polymer fuel cells both for stationary and transport applications. Other research efforts focus on the development of more corrosion-resistant electrodes for molten-carbonate fuel cells and on the scaling-up of solid oxide fuel cells to 7 mW for buildings applications. Projects also aim to produce innovative proton exchange membrane fuel cell designs that can substantially reduce the costs of fuel cells for transportation applications to less than $200/kW.

Transportation Energy Efficiency. Projects in this research area focus primarily on the development of decision support tools to support transportation-related R&D projects. The program also supports efforts to develop energy-efficient and low- or zero-emissions vehicle technologies, including advanced battery systems and supercapacitors to power electric and hybrid-electric vehicles, vehicle mounted reformer/fuel-cell systems, auxiliary energy storage and converter devices, and electrical and hybrid vehicle systems.

Renewable Energy *($100 million/year 1994-1998)*

The main objective of this technology area is to facilitate the introduction of renewable energies into the European energy system, thereby enhancing environmental protection and long-term security of energy supply. Major research areas and illustrative project activities are outlined below.

Solar photovoltaics (PV). The main objective of the EU's funding in this area is to reduce the cost of PV systems to make them competitive in future electricity markets. R&D efforts focus on achieving a production cost level of $1/Wp for multi-megawatt production lines. The EU has adopted a targeted approach to the demonstration of PV systems, operating in close collaboration with key European policy makers, executives, and financing institutions. This approach aims to raise awareness and confidence in PV-based generation and to stimulate larger markets for PV deployment in the EU and overseas, particularly in developing countries. These efforts are intended to help reduce the costs associated with solar energy and technologies. Projects also focus on the development of singe cell module integrated converter systems for grid-connected applications, and the fast production (1 wafer per second) of high efficiency crystalline solar cells using low cost materials to improve scale economies.

Renewable energy in buildings. Funding in this area aims to further sustainable energy use in the built environment. Demonstration of active and passive technologies, including advanced window coatings and urban planning techniques to optimize passive solar design, are being pursued to promote use of solar energy for heating, cooling and lighting

both in the retrofitting of existing buildings and in the construction of new, low-energy buildings. The involvement of leading architects in the program aims to foster the dissemination of advanced technologies to the market.

Wind energy. The general objective is to stimulate a wider penetration of wind energy in the EU by decreasing the cost of wind-generated electricity and by improving wind turbines in relation to reliability and public acceptability (e.g. noise and aesthetics). Efforts are being made to develop the use of unconventional sites, especially in more complex terrains and harsh climates, in regions with lower wind speeds and in regions with very high wind speeds. For example, project activities aim to design wind turbines with heated blades and gearboxes, and sensor technologies for deployment in cold climates where ice build-up often detracts from turbine performance. Other projects examine various wind technology applications, for instance in the desalination of sea water.

Energy from biomass and waste. The main objective is to increase the use of biomass for energy supply in the EU on as large a scale as possible. Demonstration projects aim to show the feasibility of biomass production, for instance through agro-energy farms on marginal lands, and to improve the economic competitiveness of biomass conversion plants. R&D aims to develop a new range of technologies that permit the use of biomass at lower costs and reduced environmental impact. Research projects also aim to develop flash pyrolysis oil (biofuel oil) for larger scale use in power plants and boilers throughout Europe, and to develop networks of biofuel producers, transporters, and consumers. Development of hydrogen-rich gas from biomass gasification for use in fuel cells is also being researched.

Hydropower. The main objective of this area (limited to demonstration activities) is to exploit a broader range of sites for the construction of small hydropower plants in order to increase overall hydroelectric capacity in the EU. Furthermore, the use of EU research funds for the upgrading and refurbishment of previously developed sites or existing plants is also being considered.

Geothermal energy. The objective of R&D in this area is to construct a hot dry rock pilot plant in Europe, to demonstrate that water injected into a stimulated fractured reservoir can be recovered through one or more production boreholes at a rate and duration which will provide the confidence for industry to build a commercial prototype. Demonstration projects aim to develop new means of thermal energy recovery and to improve the reliability of plant equipment.

Energy storage and further options. The main objective is to develop new pilot storage devices (e.g. batteries, flywheels, hydrogen) and pilot plants (e.g., direct solar steam plants) for use with renewable energy systems. Other technology R&D projects aim to develop a variable pitch turbine and high speed valve for the Azores oscillating water column. Demonstration projects are seeking to achieve industrial scale electricity production from solar thermal electricity (combined solar-gas) and wave and tidal energy.

Integration of renewable energies. This area promotes the integration of renewables into society and into energy markets. It addresses technical issues on both the supply and demand sides, and considers economic and social aspects of renewables. The task is being implemented in cooperation with professional organizations and authorities at the local, regional and national level, and with European industry and small and medium enterprises. Current projects include cost-benefit analyses and environmental assessments of biomass energy in Europe, assessment of the potential environmental and greenhouse gas emissions reduction role that fuel wood might play in the future, and the valuation of renewable electricity under different future European energy scenarios.

Fossil Fuels *($62 million/year 1994-1998)*

Activities in this area aim to realize a reduction of all energy-related emissions, to increase the efficiency of fossil energy conversion and use, and to improve the economic viability of fossil-fuel based power plants. Activities in this area address the improvement of coal-based energy conversion systems with a view to reducing their environmental impacts, basic research on combustion, improved hydrocarbon fuels for transport, and improved exploration procedures for EU-based hydrocarbon resources. Support under the demonstration programme concerns all major fossil fuels: solid fuels, oil, and natural gas. Under the Fifth Framework Programme, projects will include large-scale generation of electricity and/or heat with reduced CO_2 emissions from coal, distributed generation technologies, and systems for carbon capture and sequestration. A major goal of the program is the deployment of technologies that will permit a 20% reduction of Europe's CO_2 emissions over the next 5-10 years.

In the Fifth Framework Programme, fossil fuel R&D activities will be included in a broader energy R&D objective, the development of cleaner energy systems. This will be funded at a level of approximately $138 million per year. In addition to fossil fuel R&D, the new program will include efforts to develop and demonstrate distributed generation technologies such as hydrogen fuel cells, and to further the integration renewable energy technologies, particularly biomass, solar, and wind, into existing networked energy systems.[51]

Clean coal technologies. The main objective of projects in this area is to support the demonstration of a new generation of clean coal technology to improve the ecological and economical acceptability of coal-based power production. Efforts focus on the improvement of conventional coal technologies, such as integrated gasified combined cycle (IGCC) plants, research on co-gasification of biomass and coal, and new processes for the dry removal of SO_2 and NOx from flue gases.

Combustion research. The objective is to support theoretical and experimental work for clean and efficient combustion. It includes the development of theoretical models describing complex physical and chemical phenomena occurring during combustion. On the experimental side, efforts focus on the development of advanced diagnostic tools to allow the collection and visualization of experimental data.

New fuels for transport. The main objectives of this work are to ensure the continued availability of acceptable transport fuels by improving the inter-conversion of hydrocarbons, and to develop cleaner fuels and improve exhaust gas clean-up, in order to meet air quality requirements throughout the fuel cycle. Projects currently in progress seek to develop new technologies for the desulphurization of gasoline, and the development of new catalytic cracking processes that will permit the more efficient use of hydrocarbon feedstocks.

Oil and Gas Exploration and Reservoir Characterization. R&D actions focus on the development of new, more efficient technologies to optimize reservoir characterization and management, to identify deep complex structures and to improve the knowledge of mechanisms controlling the formation, preservation or destruction of hydrocarbon accumulations. Demonstration actions focus on technologies for exploration, production and transport of hydrocarbons as well as natural gas conversion and marginal gas field technology.

Socio-Economic and Policy Research *($11 million/year 1994-1998)*
The EU sponsors a variety of social science and policy analysis activities in the energy area. Projects focus on: analysis of global energy-environmental issues in support of the development of a European energy and technology strategy; study of the energy technology innovation process; energy and economic modeling; outreach to the broader research, industry, and policy communities; and dissemination of information and research results.

Dissemination of Energy Technologies *($5 million/year 1994-1998)*
Activities in this area include market conditioning through the dissemination of product information, advice on the application of new energy technologies, and distribution of information regarding financing options and institutions.

Nuclear Energy R&D In The 4th Framework Programme ($296 Million/Year)

EU nuclear energy research focuses on two major themes: nuclear fission safety, including the control of nuclear materials and nuclear waste disposal, and thermonuclear fusion research. Since the EU now considers fission reactor technologies to be mature, and since no new nuclear power plants are on order in Europe, no EU R&D resources are devoted to the development of new fission reactor designs. Descriptions of major nuclear fission and fusion research activities under the Fourth Framework Programme are provided below.

Nuclear Fission Safety *($98 Million/Year 1994-1998)*[52]

The objectives of the nuclear fission program are to ensure the safety of Europe's nuclear power installations and improve the competitiveness of the nuclear industry; to ensure the protection of workers and the public from radiation; to support the application of international safeguards on nuclear materials; and to help ensure the safe and effective management and final disposal of radioactive waste.

Research focuses on the many dimensions of safety in existing nuclear installations including those related to the extension of reactor life spans, fuel cycle safety and nonproliferation (in conjunction with the International Atomic Energy Agency). In addition, research will focus on strategies and methods for the prevention and management of nuclear accidents; best practices for decommissioning of nuclear facilities; safety and efficiency of future systems, including study of advanced and more efficient fuels; and new facility concepts.

The program also focuses on cooperation with the countries of eastern and central Europe and the former Soviet Union. Work in this area aims to assist these countries in the improvement of the safety of their reactors, waste management, assessment of long-term health effects of radiation exposure, and control of fissile materials.

The nuclear fission safety R&D portfolio under the Fifth Framework Programme will closely resemble that of the previous program. Nuclear fission safety and related basic science activities will be funded at a level of approximately $56 million annually in the Fifth Framework.

Controlled Thermonuclear Fusion *($198 Million/Year 1994-1998)*[53]

The long-term objective of the controlled thermonuclear fusion program is the production of safe, environmentally sound prototype reactors. It unifies, in a single program, all activities of the EU member states and Switzerland in the field of controlled thermonuclear fusion by magnetic confinement. This collaboration among fusion laboratories throughout Europe has enabled the construction of the Joint European Torus (JET), the largest installation of its kind.

For the period 1994-1998, the priority objective has been the establishment of the engineering design of the Next Step experimental reactor within the framework of the quadripartite cooperation (European Atomic Energy Community, Japan, Russia, and the USA) in the Engineering Design Activities (EDA) for an International Thermonuclear Experimental Reactor (ITER) programme. The Next Step reactor aims to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes. Research conducted under the programme looks at potential improvements in plasma physics and plasma engineering, and sets out, over the longer term, to develop the technologies to realize fusion as a commercial energy source.

Key research in the controlled thermonuclear fusion programme under the Fourth Framework Programme includes: (1) improvement of the Tokamak reactor, including finalization of the Next Step reactor design and preparation for its operation, (2) design

and prototype development of a large stellarator reactor, and (3) a long-term fusion technology effort focusing on the environmental acceptability, safety, and economic viability of fusion technologies. Projects also focus on the development of tritium breeding blankets and the development and testing of radiation-resistant and low-activation materials.[54]

The long-term objective of EU fusion activities is the creation of prototype reactors for power stations to meet society's future energy needs in a manner that is safe, environmental compatible, and economic. The proposed strategy to achieve this objective includes the development of an experimental reactor (the Next Step) followed by a demonstration reactor (DEMO). The EU believes that the construction of an experimental reactor is necessary and, in light of progress to date, now appears to be technically feasible during the next decade. This will take place within the framework of broader international cooperation, such as the international thermonuclear experimental reactor (ITER), involving the United States, Canada, Japan, and Russia as well as the EU.

During the period of the Fifth Framework Programme, implementation of the strategy will entail Next Step technology development activities such as fusion physics research. The completion of the Joint European Torus (JET) and the participation of European industry will play central roles in the development of the capacity to construct and operate the experimental reactor. The EU will continue to participate in the detailed engineering design activities (EDA), including the establishment of procurement specifications, and licensing preparations for ITER. Annual fusion R&D expenditures under the Fifth Framework are estimated at $241 million.

EU-Sponsored Non-R&D Energy Programs Outside The Framework Programme

In addition to the major energy R&D efforts carried out under the Framework Programme, the EU sponsors several other programs that support the Framework activities. These programs promote the demonstration and deployment of new energy technologies, foster the development and coordination of energy policies among EU member states and between the EU and other countries, and aim to further energy technology and policy cooperation with developing countries and regions. In addition to their goals of promoting more efficient and sustainable energy systems around the world, these EU programs also clearly have the aim of deploying European energy products in the world market and positioning European firms as major competitors in future markets for energy technologies and services. Several of the EU's non-Framework energy programs are described below.

SAVE II

SAVE II is the European Union's non-technological program aimed at promoting energy efficiency throughout Europe. SAVE II program initiatives include product labeling and equipment standards, pilot actions aimed at accelerating energy efficiency investments, dissemination of information, monitoring of energy efficiency progress at the national and EU levels and energy efficiency policy coordination among EU member states. The total SAVE II budget for the period 1996-2000 is $47 million (approximately $11.8 million per year).[55]

SYNERGY

With a 1997 budget of $7.2 million, the SYNERGY program promotes energy policy cooperation between EU countries and third countries in Asia, Latin America, Africa, and the Middle East. These projects aim to contribute to EU energy and economic goals such as the international economic competitiveness of Europe's energy industries, energy supply security, and global environmental protection. For example, projects in Asia and Latin America aim to promote the diffusion of European energy technologies into these markets, while projects in the Persian Gulf region support an ongoing energy security dialogue with countries in that region. SYNERGY provides advice and training in energy policy; analysis and forecasting in energy matters; conference and seminar organization; and support for regional cooperation.[56] Ongoing policy dialogues and cooperative efforts initiated under the SYNERGY program include the Euro-Mediterranean Forum, the Balkans Task Force, and the new China-European Community Group.[57]

ALTENER II

ALTENER II is the European Union's program promoting the use of renewable energy sources within the EU, and in selected countries in Central and Eastern Europe and the Mediterranean. Its actions are specifically designed to overcome barriers to accelerate the penetration of renewable energy sources and encourage investment. Program activities include studies aiming to support and complement Community and Member

States´ efforts to develop the potential of renewable energy sources and pilot actions aimed at creating or extending renewable energy infrastructure. ALTENER, which provides up to 50% support for pilot projects and up to 100% support for feasibility studies and market analyses, also promotes information dissemination, provides advice to investors, and coordinates national, regional and local initiatives to accelerate the market penetration of renewable energy sources. The five-year budget (1993-1997) for ALTENER was $45 million (approximately $11.2 million annually); its successor program, ALTENER II, which operates from 1998-2002 has a budget of $30 million.[58]

PHARE and TACIS

The EU's technical assistance programs aim to develop capacity and management skills, and provide advice and expertise as well as direct financing for infrastructure projects in the energy sector of countries outside the EU. Each of the technical assistance programs has a different geographic focus; PHARE sponsors projects in Central and Eastern Europe, while TACIS operates in the Newly Independent States and Mongolia. The technical assistance programs are designed to support the broader policy objectives of the EU in the respective regions. Projects are financed by a variety of funding mechanisms including the European Development Fund and the European Investment Bank. Between 1994-1996 PHARE's total budget was $176 million ($88 million annually), while that of TACIS was $460 million ($230 million annually). [59]

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[1] Eurostat, Statistical Office of the European Communities, 1997. *Eurostat Yearbook '97*. This figure represents the cumulative population of the fifteen EU Member States.

[2] Ibid. This sum represents the cumulative GDP of all fifteen EU Member States. Throughout this report, financial data are reported in 1995 purchasing power parity U.S. dollars. The currency deflators used in converting ECU to U.S. dollars are those published by the Organization for Economic Cooperation and Development. See OECD, Statistics Directorate, *National Accounts 1960-1996: Main Aggregates Volume 1* (Paris: OECD, 1998).

[3] Community Research and Development Information Service (CORDIS), http://www.cordis.lu/en/src/i_004_en.htm. Includes only activities associated with the European Union's Fourth Framework Programme 1995-1998.

[4] Luca Guzetti, *A Brief History of European Union Research Policy* (Luxembourg: Office for Official Publications of the European Communities, 1995), pp. 54-56.

[5] Presentation by Birgit Baumann, European Commission Directorate General XII, at the International Energy Agency Workshop on Energy RTD Trends, September 19, 1997.

[6] Commission of the European Communities, *EC Research Funding*, 3rd Fully Revised Edition (Luxembourg: Office for Official Publications of the European Communities, 1992); European Commission, EC Research Funding (Luxembourg: Office for Official Publications of the European Communities, 1996).

[7] European Commission, Fifth Framework Programme 1998-2002, http://www.cordis.lu/fp5/src/over.htm

[8] European Commission, *EC Research Funding* (Luxembourg: Office for Official Publications of the European Union, 1996), p. 27.

[9] OJ L 64/5 12.3.1999; OJ L 64/24 12.3.1999; OJ L 64/62 12.3.1999; OJ L 64/44 12.3.1999; OJ L 64/82 12.3.1999; OJ L 64/95 12.3.1999; OJ L 64/109 12.3.1999; OJ L 64/130 12.3.1999; OJ L 64/145 12.3.1999; OJ L 64/157 12.3.1999.

[10] European Commission, *EC Research Funding*, p. 28.

[11] OJ L 64/1 12.3.99.

[12] European Commission, "Toward the Fifth Framework Programme: Scientific and Technological Objectives" EUR-17531 (Luxembourg: Office for Official Publications of the European Communities, 1997); European Commission, "Inventing Tomorrow: Europe's Research at the Service of Its People," EUR-16961 (Luxembourg: Office for Official Publications of the European Communities, 1996); http://www.cordis.lu/fifth/src/sp1.htm.
[13] European Commission, "Setting Course for the XXIst Century: Main Thrust of the Fifth Framework Programme," *RTD Info* April-May 1997, pp 5-7; http://www.cordis.lu/fifth/src/cc-4.htm
[14] http://www.cordis.lu/fp5/src/budget7.htm
[15] European Commission, *Research and Technological Development Activities of the European Union Annual Report 1995* (Luxembourg: Office for Official Publications of the European Communities, 1996), p. 17.
[16] European Commission, Directorate General XII (Science, Research, and Technology), *The Fourth Framework Programme (1994-1998)*, Luxembourg: Office for Official Publications of the European Communities, 1994, pp. 35-36.
[17] British Petroleum, "BP Statistical review of World Energy 1998."
[18] European Commission, "An Energy Policy for the European Union," COM(95)682.
[19] COM(95)682, p.2.
[20] OJ L 64/63, 12.3.1999.
[21] European Commission, Directorate General for Energy (DGXVII), "Trans-European Energy Networks: Policy and Actions of the European Community," (Luxembourg: Office for Official Publications of the European Communities, 1997), pp. 4-7.
[22] Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 Concerning Common Rules for the Internal Market in Electricity.
[23] Directive 96/92/EC; see also http://europa.eu.int/en/comm/dg17/elec/faq.htm
[24] European Commission, "Opening Up to Choice: The Single Electricity Market," (January 1999), pp. 4-9.
[25] 13347/1/97 REV 1, "Common Position Adopted by the Council on 12 February 1998."
[26] Klom, A.M., "Electricity Deregulation in the European Union," *Energy In Europe* No. 27, p. 6. http://europa.eu.int/en/comm/dg17/27klom.htm.
[27] European Commission, "An Overall View of Energy Policy and Actions," COM (97), Draft of 21 April 1997.
[28] See: Gunther Rexrodt, "Energy Policy in the European Union," Energy in Europe No. 24, http://europa.eu.int/en/comm/dg17/24rex_en.htm; Council Regulation (EC)701/97, 14 April 1997.
[29] "An Overall View of Energy Policy and Actions," *Energy in Europe* No. 28 (July 1997), p. 39.
[30] Statement of Energy Commissioner Christos Papoutsis (Directorate General XVII), quoted in "An Overall View of Energy Policy and Actions," *Energy in Europe* No. 28 (July 1997), p. 39.
[31] COM(95)682.
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