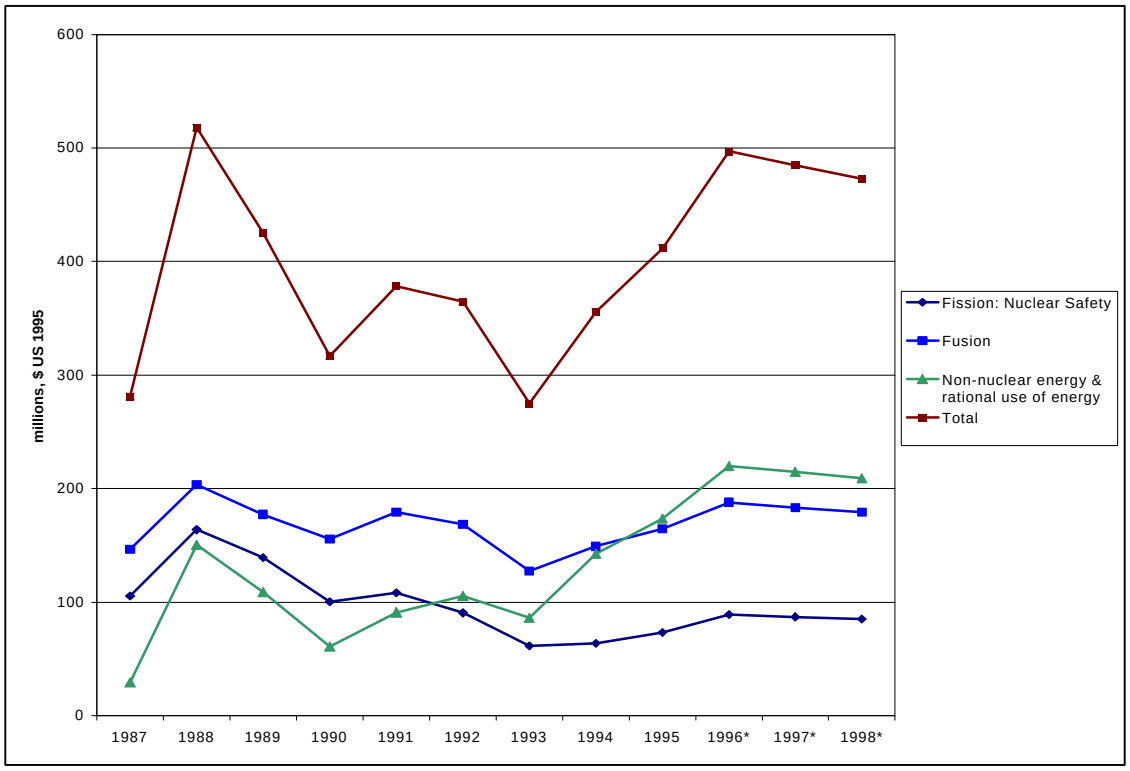
EU Energy R&D

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.[i] 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[ii]



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.[1]

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.[iii]

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[iv]

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.[2] 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

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[1] 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.

[2] 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)[v]

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[vi] *($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.[vii]

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)*[viii]

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)*[ix]

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.[x]

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).[xi]

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.[xii] 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.[xiii]

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.[xiv]

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). [xv]

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

[ii] European Commission, Directorate General XI I (Science, Research, and Technology), The Fourth Framework Programme, Luxembourg: Office for Official Publications of the European Communities, 1994. Data for 1996-1998 in this figure are estimated average annual expenditures, based on OECD ECU-US dollar exchange rates.

[iii] European Commission, Directorate General XI I (Science, Research, and Technology), The Fourth Framework Programme, Luxembourg: Office for Official Publications of the European Communities, 1994 pp. 24-29.

[iv] Information in this section is from CORDIS, http://www.cordis.lu/fp5/src/t-4.htm

[v] Information used in preparing descriptions of EU non-nuclear energy R&D programs provided here is from Joule: Work Programme-Research Priorities, www.cordis.lu/joule/src/workprog.htm

[vi] 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. 42; European Commission, Directorate General for Energy, *THERMIE: Demonstration of Energy Technologies, Activity Report 1997* (Luxembourg: Office for Official Publications of the European Communities, 1997), p. 27.

[vii] OJ L 64/73, 12 March 1999.

[viii] Information used in preparing this summary of EU nuclear fission safety programs is from: http://europa.eu.int/comm/dg12/fission1.html

[ix] Information used in preparing this summary of EU fusion R&D programs is from: http://apollo.cordis.lu/cordis-cgi/srchidadb?CALLER=FUSION_12C

[x] "Workplan for Specific Programme on Controlled Thermonuclear Fusion, 1994-1998," http://apollo.cordis.lu/cordis-cgi/srchidadb?ACTION=D&SESSION=35361998-11-4&DOC=1

[xi] http://europa.eu.int/savcall2.doc

[xii] http://europa.eu.int/en/comm/dg17/synform.doc

[xiii] European Commission, "An Overall View of Energy Policy and Actions," COM (97), 21 April 1997.

[xiv] http://www.europa.eu.int/en/comm/dg17/altenib.doc; see also: European Commission, "An Overall View of Energy Policy and Actions," COM (97), 21 April 1997.

[xv] European Commission, "An Overall View of Energy Policy and Actions," COM (97), 21 April 1997; http://europa.eu.int.