External Factors Affecting Fusion Energy Development

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Abstract

A number of external factors affecting the pace and direction of fusion energy development are reviewed and discussed. These include the changing electric utility marketplace environment, the availability of fossil fuels, competing power sources, and environmental issues.

Introduction

Fusion energy research and development has been underway for close to half a century. Over $10 billion (as-spent dollars) has been allocated to this effort in the U.S. over this period and a comparable (possibly larger) amount has been spent by other countries. Currently, the U.S. Department of Energy spends about $225 million per year on fusion energy sciences and about $500 million per year on inertial confinement fusion in support of its nuclear weapons Science-Based Stockpile Stewardship program, of which $284 million is earmarked for construction of the laser-based National Ignition Facility in FY 1999.

In 1992, the European Union, Japan, Russia and the United States initiated a serious engineering design effort aimed at construction of a fusion engineering test facility, the International Thermonuclear Experimental Reactor (ITER), capable of producing over 1000 Megawatts of fusion power, initially for 15 minutes at a time, but subsequently continuously. The facility aims to begin operation during the first decade of the 21st Century. If constructed, ITER would be a major milepost on the road to practical fusion power.

Critics assert that the cost of ITER, estimated to be in the $8-10 billion range, raises serious doubts whether fusion would ever compete economically against other energy sources. The ITER is based on the "tokamak" magnetic confinement principle, which has been the most, some would say only, successful scientific path to fusion demonstrated to date.

Political events in the United States, evidenced by a factor of two reduction in civilian fusion funding in FY 1996, caused a restructuring and renaming of the U.S. fusion program. Now called the "Fusion Energy Sciences Program," its goal is to "advance plasma science, fusion science, and fusion technology-the knowledge base for an economically and environmentally attractive fusion energy source." In particular, the U.S. abandoned its previous 2025 target date for operation of a fusion demonstration power plant and now has no timetable for the commercial deployment of fusion.

In a report accompanying the FY 1999 budget, the House-Senate Appropriations committees told the U.S. Department of Energy to complete and close out its ITER related activities in FY 1999, saying "The conferees note that the Department continues to emphasize tokamak development at the expense of other promising technologies. The conferees continue to be very supportive of the increased emphasis on innovative confinement concepts and university-based experiments."

A number of grass-roots environmental organizations have expressed largely negative opinions on fusion, though fusion is, for the most

part, not on their political agendas. However, following Congressional passage of the FY 1999 budget, Scott Denman, Executive Director of the Washington-based Safe Energy Communications Council (SECC), lauded the Congressional action on ITER and called for Congress to end support for all nuclear programs, including fusion.[1]

In light of the above and other related events, the U.S. fusion program is engaged in a multipronged reexamination of its program content and priorities. In August 1997, Fusion Power Associates held a 3-day symposium, "Pathways to Fusion Power," aimed at high-level consideration of a number of fundamental issues facing the fusion program[2]. In April 1998, the University Fusion Association and other institutions sponsored a week-long workshop in Madison, Wisconsin, on the theme "Forum for Major Next-Step Fusion Experiments." At that workshop, the inertial confinement fusion community, previously a minor player in fusion energy development though a centerpiece of the nuclear weapons stockpile stewardship program, presented a thoughtful and challenging fusion energy development strategy based on inertial confinement. In presenting the strategy, Lawrence Livermore National Laboratory Associate Director for Lasers, Mike Campbell, said we must "address the concerns about the present fusion program, not just the need for good science, but also the need for better end products and lower cost development paths."

The Department of Energy has recently set in motion three interrelated fusion program reviews for 1998-99[3]: one by its Fusion Energy Sciences Advisory Committee, one by the Secretary of Energy Advisory Board and one by the National Research Council. In addition, Fusion Power Associates and UCLA will sponsor a three-day workshop, January 25-27, 1999, on the theme "Cost Effective Steps to Fusion Power," and the University Fusion Association, with other co-sponsoring institutions, is planning a two-week Fusion Summer Study, July 11-23, 1999, in Snowmass, Colorado, aimed at building community consensus for the future direction of the fusion program.

In this report, a number of issues and viewpoints, external to the fusion technical program, are reviewed and discussed. These include the changing electric utility marketplace, the availability of fossil fuels, competing power sources, and environmental concerns.

The Electric Utility Marketplace

On a fundamental level, the U. S. fusion energy program must pay attention to the electric utility marketplace because eventual electricity production is the ultimate purpose of the research.

In the early 1990's, Fusion Power Associates. with private funding, conducted a study on how to accelerate the development of fusion, based on the construction of a "pilot plant" with full involvement of the electric utilities[4,5]. An experienced electric utility executive, W. G. Morison of Ontario Hydro, was a member of the study team. The report provides a discussion of "*Characteristics of Fusion Pilot Plants of Interest to Utilities*" and concludes, "While utilities would eventually have an interest in knowing all about new and innovative scientific features of a fusion energy system, their initial interest would be in the areas which they have direct responsibility for in building, operating and maintaining a reliable, economic electric power supply system. This would include:

(1) Production and extraction of high grade heat

(2) Operation and maintenance

(3) Instrumentation, control and protection

(4) Safety, environment and licensing

(5) Fuel cycle and tritium self-sufficiency

(6) Waste management and decommissioning

(7) Utility input in design for ease of construction, operation and maintenance

During the 1980's some fusion research, up to a level of about $4 million per year, was funded in the U.S. by the Electric Power Research Institute (EPRI). The electric utility industry and EPRI have a vastly different sense of their interests and priorities today than they did in the 1980's and earlier. Not only are they more tightly focused on the near-term, they are also in the midst of a deregulation experience that does not bode well for enhancing their interest in new energy technologies for the long-term. Furthermore, unless the new technologies offer substantial economic advantage, and/or capability to alleviate burdensome environmental restrictions, they will not be embraced by the U.S. electric utility industry.

In 1992, a group of EPRI executives, led by EPRI VP Robert L. Hirsch, conducted a "Fusion Study" and issued a report[6]. They concluded, in part,

(1) "Because commercialization is a long way off and this field of technology is highly complex, there are significant tradeoffs to be made. Accordingly, program diversity beyond Tokamaks is important;"

(2) "In diversifying its fusion program, DOE should give special consideration to the following:

  (a) Concepts and/or designs that may be less complex

  (b) Power plant designs without tritium burning, because of the very serious materials problems associated with 14 MeV neutrons

  (c) Use of certain low activation materials

  (d) High overall energy conversion efficiency, e.g., combined direct electrical and thermal conversion

  (e) The outage and waste disposal problems of changing out large volumes of fusion reactor core materials every few years

  (f) The importance of effective ash removal from fusion plasmas

(3) Engineering thinking and eventual need of the marketplace should become a critical element in fusion program planning and decision making.

In 1994, EPRI formed an ad hoc "EPRI Fusion Panel," under the chairmanship of Jack Kaslow, Executive Director, EPRI Northeast Region, and expanded on its 1992 report. Their report[7] states, "In a thorough review of practical fusion power system characteristics, three criterion groups of overarching importance emerged:

(1) Economics

(2) Public acceptance

(3) Regulatory simplicity

Each is discussed in the report. In a summary statement, the Panel's chairman states, "Fusion power's potential benefits to humanity and the environment are immense. It may allow large-scale electricity production anywhere, with virtually no natural resource depletion or environmental pollution. Over the past 40 years, dedicated researchers around the world have taken fusion power from an abstract concept to a real possibility. Many more years of work remain before practical fusion power systems become a reality-but dramatic demonstrations have established scientific feasibility, and large research programs continue to press toward practical use."

Several other marketplace factors for fusion researchers to consider have been described by J. W. Anderson[8]. These include

(1) Utility investor attitudes *(Do stockholders want utility executives to invest their money in fusion)*

(2) Impact of deregulation *(The shift to natural gas is resulting in a lot of "stranded assets,")*

(3) The future of nuclear fission *(The emergence of a few large entities owning many*

nuclear plants would be the most likely place to market fusion).

Projections for Fossil Fuel Availability

The burning of fossil fuels dominates the nation's and the world's energy consumption, accounting for approximately 90% of energy supply in the approximate percentages of 40% oil, 25% natural gas, 25% coal[9]. The balance is supplied by nuclear and hydro in roughly equal proportion. Electricity generation in the U. S. accounts for about 30% of total energy consumption, and is about 70% fossil fuel-based, 20% nuclear and 10% other (mostly hydro). Though much touted, renewables other than hydro provide only about 3% of the Nation's electricity, almost all of which comes from burning of biomass. The fossil fuel mix for electricity production is about 52% coal, 16% natural gas and 2% oil. Though natural gas is currently the option of choice for new production. due to low cost compared to coal and oil, projections indicate that economic recovery of natural gas will peak around 2040, requiring advanced technologies to stretch its use to later in the century. Thus, presumably, around the middle of the century, electric utilities will shift back towards coal as the option of choice, barring other environmental or economic factors against it.

The U.S. has about 250 billion tons of proven coal reserves and is consuming coal at an annual rate of about 1 billion tons. The U.S. has about 5 trillion cubic meters of proven reserves of natural gas and is currently consuming natural gas at a rate of about 0.6 trillion cubic meters per year. Total world proven reserves of natural gas are about 150 trillion cubic meters; current world consumption rate is about 2 trillion cubic meters per year. The world proven reserves of oil are about 1000 billion barrels; current world consumption rate is about 25 billion barrels per year[10].

The above data suggests that oil and gas will begin to be in short supply, resulting in higher prices, by the middle of the century. Forecasters can project wide variances depending on such factors as projected rate of increase in consumption, discoveries of new reserves and use of advanced recovery techniques.

Competing Power Sources

Fusion is expected to enter the marketplace at a time when fossil fuel use is in the decline, from some combination of short supplies, higher price and environmental restrictions. At that time the primary competing sources will be so-called "renewables" and nuclear fission. Fusion researchers must keep a close watch on the evolution of the competition.

The primary renewable competing sources are solar thermal, photovoltaics, wind, geothermal and biomass. These technologies are technically feasible today but genera]]y are not cost-competitive with fossil fuels. However, costs have come down dramatically since 1980 (Figure 1) and further reductions are forecast. [9]

Fusion, as a large, central station nuclear technology, is most likely to compete in markets that are also attractive for nuclear fission power plants. Although nuclear power provides 20% of U.S. generating capacity, there have been no domestic orders for new plants in over 20 years, due to a combination of economic, regulatory and political factors. As Anderson notes,[8] "The current crop of nuclear utilities are important to the future of nuclear fusion. Besides being potential customers, they will be opinion leaders for (or against) fusion."

In a world market where radioactive waste disposal procedures have become established and accepted, nuclear fission power will likely have an economic edge on fusion, due to the relative simplicity of its technology. In a world where waste disposal is still controversial, as it is today, fusion will have the formidable challenge of differentiating its waste disposal issues from those of fission.

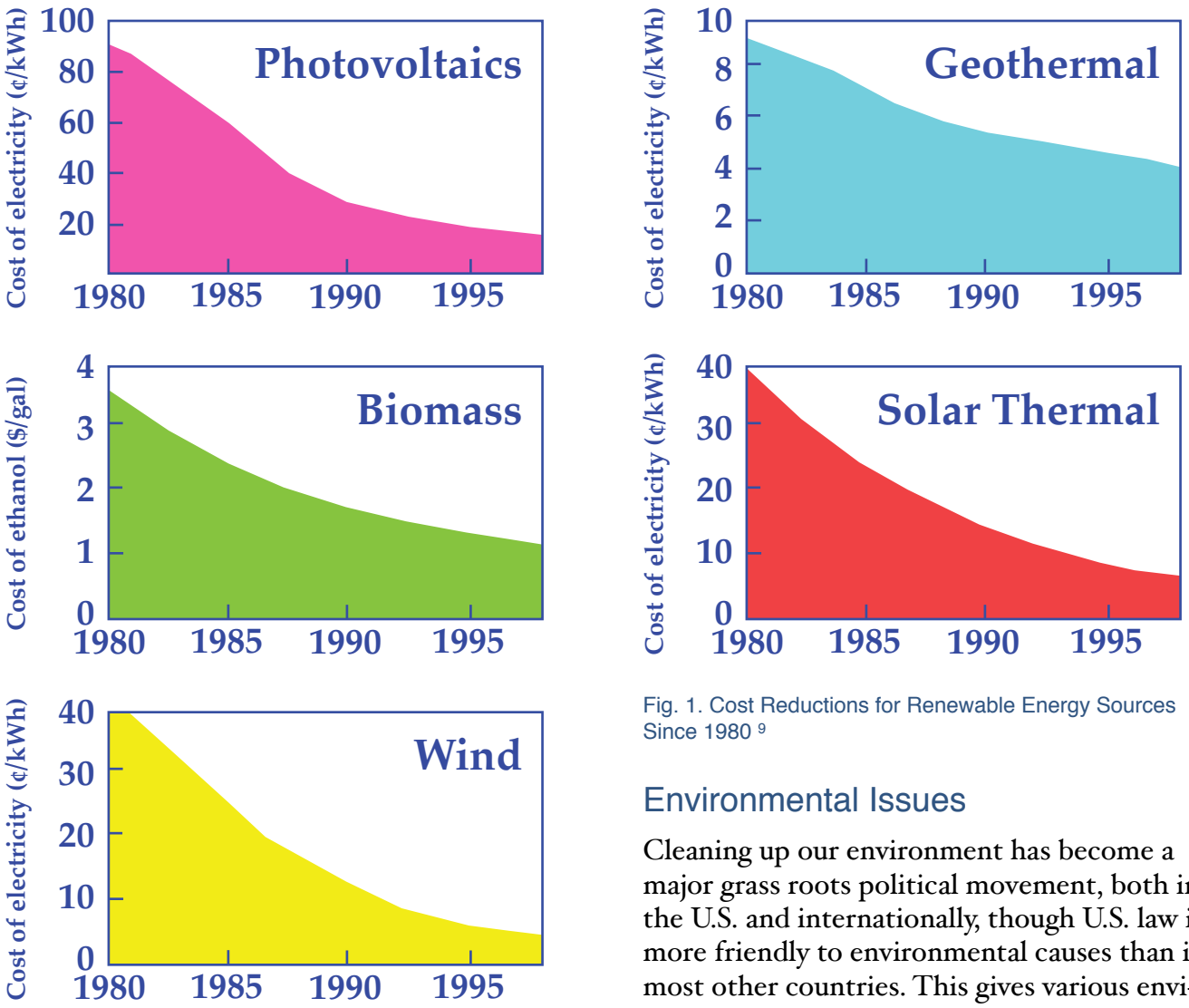

Fig. 1. Cost Reductions for Renewable Energy Sources Since 1980 [9]

Environmental Issues

Cleaning up our environment has become a major grass roots political movement, both in the U.S. and internationally, though U.S. law is more friendly to environmental causes than in most other countries. This gives various environmental grass roots organizations considerable political influence, though still not comparable to that of big business. The interests of environmental organizations frequently conflict with those of big business, but environmental groups can claim their share of victories.

For the most part "fusion is not on the radar screen of environmental organizations."[11] However, several environmental organizations have paid some attention to fusion. Three in particular, the Natural Resources Defense Council (NRDC), the Safe Energy Communication Council (SECC), and the U.S. Public Interest Research Group (U.S. PIRG) have expressed public opinions on aspects of the fusion program.

The NRDC states that its purpose is "to safeguard the Earth: its people, its plants and animals, and the natural systems on which all life depends." Among other things, NRDC states that it "strives to help create a new way of life for humankind, one that can be sustained indefinitely without fouling or depleting the resources that support all life on Earth." Among the "issues that affect all life on earth," the NRDC lists "global warming." To that end, NRDC advocates "advancing clean energy technologies," including fuel cells, photovoltaics, wind turbines and "other clean energy technologies." NRDC states that its "primary strategies" are:

(1) Scientific research (determining the facts)

(2) Public education (getting the word out)

(3) Lobbying (persuading Congress to act)

(4) Litigation (suing the bad guys)

NRDC has taken an aggressive stand against construction of the National Ignition Facility (NIF) because they believe it will unnecessarily maintain nuclear weapon development capabilities in the DOE laboratories. They initiated a law suit to stop construction of the NIF on the basis that the DOE had not performed an adequate environmental impact analysis. The judge refused to stop construction, though he mandated additional environmental analysis. The NRDC has not opposed the development of fusion for civilian power production. Tom Cochran of NRDC has served on the DOE's Fusion Energy Advisory Committee, during which time he supported fusion research and development on magnetic confinement research but not on the Defense Program's inertial confinement fusion effort. Matthew McKinzie of NRDC attended the meeting with fusion program personnel at which he indicated that NRDC believes that magnetic fusion "will not get ignition in our lifetime" and therefore does not pose major policy problems for NRDC. They seek to reduce reliance on nuclear weapons, therefore they are concerned about the projected achievement of ignition in the near future on NIF. He said that research on magnetic fusion should be pursued "at some level" because "fusion may be greener than fission." He said that NRDC has "not attacked nuclear power," but does oppose the use of reactors to make or process plutonium because of proliferation concerns. He said that, in his opinion, "The fusion community has not come to grips with the connection between fusion and weapons."

The SECC states that it is "an environmental coalition of national energy, environmental and public interest media groups working to increase public awareness of the ability of energy efficiency and renewable energy sources to meet an increasing share of our nation's energy needs." They list as *Council Members*, groups such as Green Peace, Renew America, Media Access Project and U.S. PIRG. Christopher Moser, a Policy Associate at SECC, is primarily responsible for developing positions on environmental and energy issues. Though invited, he did not attend the recent meeting with U. S. fusion personnel. The SECC has been avidly anti-nuclear and opposes both fission and fusion. They have actively sought reductions in the fusion budget in Congress. SECC Executive Director, Scott Denman, issued a press release October 7, 1998, entitled *"Congress Phases Out International Fusion Project Funding,"* subtitled, "Funding for Commercial Nuclear Power Research Also Reduced."[1] Denman slammed the ITER project, saying, "Congress should have eliminated all ITER funding. For years this ineptly managed, ill-defined scheme to design an international prototype of a fusion reactor has seemed more like a Keystone Cops skit than a credible, scientific process."

The U.S. PIRG states that it is an "organization dedicated to serving as a watchdog for the nation's citizens and environment." They state, "Our campaigns take us wherever necessary to safeguard the public interest: to Congress. to the courts, to corporate boardrooms, to government agencies and to the news media." They say, "U.S. PIRG combines the expertise of professionals with the power of citizens in defense of clean air and water, strong safe-

guards for consumers, a free and vigorous democracy, and a way of living today that ensures a better quality of life tomorrow." Anna Aurillio, of U.S. PIRG, has been a vociferous advocate of cutting the fusion budget to increase funding for efficiency research and renewable energy sources. She attended a recent meeting with fusion program personnel.[11] She stated that U.S. PIRG was primarily interested in protecting the environment. She believes that both fossil fuels and nuclear power are bad for the environment and favors technologies like wind, biomass, geothermal and solar. Though hydro-electric power is classified by most as a "renewable" energy source, U.S. PIRG opposes large hydro stations because of their effect on the environment. Their main objection to nuclear power is the radioactive waste. In her opinion, low-level radioactive waste is not "environmentally benign." She thinks the fusion budget is too large compared to renewables; that possibly fusion could be OK, but not with D-T fuel: consequently she believes the program should concentrate on finding a non D-T system that would be "environmentally benign."

Other groups that have little more than a passing interest in fusion include Public Citizen, the Union of Concerned Scientists (UCS), the World Resources Institute (WRI), and Resources for the Future (RFF). One member of the Audubon Society (Dr. Jan Beyea) has also served in the past on fusion review panels.

Public Citizen is a citizen's group founded by Ralph Nader. In 1974 he founded the Public Citizen Critical Mass Energy Project (CMEP). Wenonah Hunter is the Director. Previously she worked for the Union of Concerned Scientists. CMEP says they are "a powerful voice for protecting America's natural resources by promoting renewable and energy efficiency technologies, watchdogging nuclear safety issues, stopping the reckless disposal of radioactive waste, ensuring that environmental and consumer interests are protected as the electric utility industry deregulates, and improving transportation policy." Among its "most notable achievements," the CMEP claims to have "convinced the Congress to terminate the Gas Turbine Modular Helium Reactor; blocked the Nuclear Waste Policy Act; and organized disparate organizations across the political spectrum in a coalition called Stop the Bailout, which works to prevent a consumer bailout of the electric industry for nuclear power plants." At a meeting with fusion personnel[11], Wenonah Hunter stated that CMEP has "zero tolerance for radioactive waste." She said that CMEP would "never support any technology that generates radioactive waste," and it was her understanding that fusion does create radioactive waste. She said, "Our view of the world is fewer large entities and more local control." She said the CMEP sees no reason "to create another big centralized, high cost technology for making power." The group favors "smalL distributed (energy) sources that bring benefits to the community and not benefits to big power plant owners." However, she said, "fusion is far enough our that it is not on our radar screen." They are too busy "fighting big companies in the here and now that are holding up environmental benefits" to pay attention to fusion. They do not support the Holdren PCAST recommendations on energy R&D because of the report's support for nUclear power. They support more emphasis on improving energy efficiency.

The Union of Concerned Scientists (UCS) says they are "an independent, non-profit alliance of 70,000 committed citizens and leading scientists across the country (who) combine scientific research with public education and citizen advocacy to ensure a clean, healthy environment and a safe world." They were founded in 1969 "by a group of faculty and students at the Massachusetts Institute of Technology who were concerned about the misuse of science and technology in society." They call for "greater emphasis on applying scientific research to pressing environmental and social problems." Their most famous spokesperson is MIT professor Henry Kendall, a member of their Board of Directors. Among their most notable accomplishments they claim to have "worked to stop missile defenses that cost bil-

lions and won't protect our country; strengthened safety standards at. every nuclear plant in the country; secured legislation to advance clean-car technologies in California and New England; encouraged the United States to sign the first global warming treaty; and enacted policies that dramatically increased the use of renewable energy in the Midwest." David Lochbaum, UCS's Nuclear Safety Engineer, at a meeting with fusion personnel[11], stated that UCS is not opposed to nuclear power, believing that "safe fission is better than dirty coal." He said that their issue time horizon tends to be around 2030, so "fusion doesn't come up much" in their discussions. He said fission turned out to be "more expensive and less safe than expected," and he thought some of the fusion rhetoric he had heard sounded like the early rhetoric of fission. He said fusion claims "great promise," but he is not sure that fusion will ever be a "reality." He said fusion needs a "cradle to grave" plan that emphasizes power plant issues, like safety and waste disposal, rather than scientific concepts.

He is not confident that the U.S. is ever going to resolve the issue of how to dispose of high level radioactive wastes. He said the UCS supports more spending on renewable energy research.

The World Resources Institute (WRI) , founded in 1982, states that it is "an independent center for policy research and technical assistance on global environmental and development issues." They say they arc "dedicated to helping governments and private organizations of all types cope with environmental, resource, and development challenges of global significance" WRY's mission is "to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of Current and future generations."

They say they "provide objective information and practical proposals for policy and institutional change that will foster environmentally sound, socially equitable development." They say they advocate "innovation, to lead change for a sustainable world" and believe that "change in human behavior is urgently needed to halt the accelerating rate of environmental deterioration." WRI Senior Associate, James J. MacKenzie, spoke at Fusion Power Associates June 1998 symposium, "Plasma Science and Its Applications." In his talk, "Energy and the Environment in the 21st Century: The Challenge of Change,"[12] he states, "Energy has played a crucial role in the evolution of the human species. Through the harnessing of various forms of energy, humankind has survived ice ages, accommodated to hostile weather, and industrialized. In a cruel reversal it now appears that-unless major changes are soon made in the forms and uses of energy uncontrolled energy consumption may also lead to far reaching, possibly irreversible, changes in the earth and its climate and to the widespread jeopardy of many forms of life itself." MacKenzie is not optimistic about the future of nuclear power. He says, "The near-term potential contribution of nuclear energy to solving the global energy-climate problem seems limited for several reasons," citing the logistical problem of deploying large numbers of the newer, safer reactors, the difficulty of poorer nations in dealing with the cost and complexity of nuclear plants, and concerns about nuclear weapons material proliferation. WRI appears to be the most technical and least political of the groups surveyed. WRI has not focused on fusion.

Resources for the Future (REF) is a "non-profit and non-partisan organization that conducts independent research-rooted primarily in economics and other social sciences-on environmental and natural resource issues." They state that "by bringing results of this research to the attention of policy makers, academicians, and people everywhere, RFF helps make possible well-reasoned decisions that ultimately shape the quality of life." Their Board members include MIT professor John Deutch and former Los Alamos National Laboratory director Don Kerr. Resources for the Future has not focused on fusion.

A selection of environmental organizations with some interest in fusion is shown in Table 1.

Table 1 — A Selection of Environmental Organizations with Some Interest in Fusion

Natural Resources Defense Council
(NRDC) 1350 New York Avenue, NW
Washington, DC 20005
(202)289-6868
www.nrdc.org
Thomas B. Cochran
Matthew McKinzie

Safe Energy Communications Council
(SECC)
1717 Massachusetts Avenue, NW
Washington, DC 20036
(202)483-8491
seccgen@aol.com
www.safeenergy.org
Scott Denman, Executive Director
Chris Moser (csmoser@aol.com)

U.S. Public Interest Research Group
(U.S. PIRG) 218 D Street, SE
Washington, DC 20003-1900
(202)546-9707
uspirg@pirg.org
www.pirg.org/
Anna Aurillo, (212)349-6420

Public Citizen Critical Mass Energy Project (CMEP) 1600 20th Street, NW
Washington, DC 20009-1009
(202) 588-1000
www.citizen.org
Wenonah Hauter, Director
(202)546-4996

Union of Concerned Scientists (UCS)
1616 P Street, NW
Washington, DC 20036
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ucs@ucsusa.org
www.ucsusa.org
David A. Lochbaum

World Resources Institute
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Darryl Banks, Program Director, Technology and Environment
James J. MacKenzie, Senior Associate

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www.rff.org

Implications for The Fusion Program

The U.S. fusion program has structured its programs and plans largely around scientific and technical issues internal to its development. External factors have largely been either a minor consideration or ignored. Considerations of external factors, such as those discussed, are playing a dominant role in determining the level of government interest and support for the fusion program. Fusion researchers and managers must give more thought to the manner in which such factors can be integrated into both policy and technical aspects of the program. A comprehensive, systems approach to fusion development, that takes into account both internal technical and external factors, is required.

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[10] British Petroleum Statistical Review of World Energy, June 1998.

[11] Meeting of Fusion and Environmental Leaders, August 13-14, 1998, Washington, DC, sponsored by the Joint Institute for Energy and Environment, Knoxville, TN.

[12] Journal Fusion Energy, Volume 17, No.2, June 1998.