Series No. 97-11

THE U.S. FUSION ENERGY SCIENCE PROGRAM: A NEW DIRECTION

JAMES F. DECKER
Deputy Director
Office of Energy Research
U.S. Department of Energy

This article is one in a series of occasional papers published by the Center for Science, Trade, and Technology Policy of George Mason University and the Science and Technology Policy Institute of Korea as part of their U.S.-Korea Science and Technology Cooperation Program. This article is drawn from Dr. Decker's presentation at the U.S.-Korea Forum on Fusion Science and Technology held on February 18-19, 1997 in Washington, D.C.
STEPI-GMU/CSTP Occasional Paper 97-11

The U.S. Fusion Energy Sciences program has undergone significant budgetary reductions in the past few years which have catalyzed a rethinking of the program's direction, and which have led to substantial changes in the program. In this article I will explain the rationale for our redirected program, as well as define the new program's mission and goals.

Fusion has great potential as an energy source to meet a significant portion of the growing energy needs of the world and to do so without contributing to carbon emissions. However, developing fusion energy is a very difficult and challenging technological endeavor.

Outstanding progress has been achieved in fusion research that can be measured both in terms of producing fusion power, and more importantly in our understanding of magnetic confinement. Despite the promise of fusion and the technical progress, funding for fusion research in the United States has declined substantially. In fiscal year 1996, there was a one-third reduction in funding by the U.S. Congress for fusion research. The reductions have forced the Department of Energy to restructure the fusion program from one which had as a mission the development of an energy technology on a clear schedule, to one that is more focused on pure science.

History of the U.S. Program

The earliest fusion efforts date back to the early 1950s when fusion research in the United States was pursued as part of the classified weapons research program. Early on, however, scientists believed that if fusion could be harnessed, it would make a valuable energy source. During the 1950s through the 1970s, many magnetic confinement approaches were investigated and it became clear that the science of fusion plasma and development of a commercial fusion reactor would be a lengthy and expensive undertaking.

In 1958, the United States declassified fusion research which opened the door to international cooperation. Contact between U.S., European, and Soviet fusion researchers continued in the 1960s, but enthusiasm began to wane until the late-1960s when the Russians announced significant advances in confinement conditions using their tokamak concept. As a result, the United States, Europe, and Japan redirected their fusion programs toward the tokamak configuration, and the United States built several small tokamaks at Oak Ridge National Laboratory, Massachusetts Institute of Technology, and General Atomics. Funding for fusion research expanded substantially from $34 million in 1970 to more than $350 million in 1979.

During this time, the Tokamak Fusion Test Reactor (TFTR) was built at Princeton Plasma Physics Laboratory. Fusion energy research programs were also supported at several national laboratories and a number of universities providing a support system for the training of many plasma physicists. Ambitious fusion programs were also undertaken during this time by Japan and the European Community, and international cooperation expanded.

Figure 1

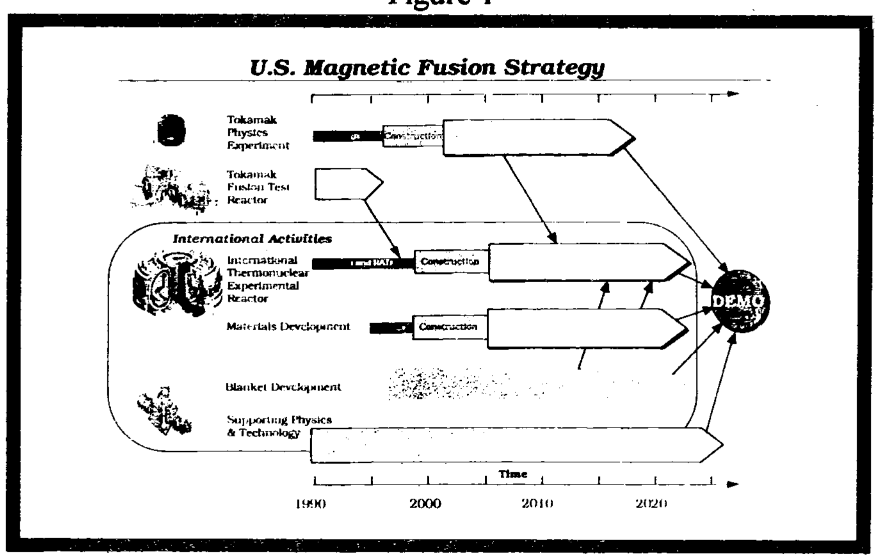
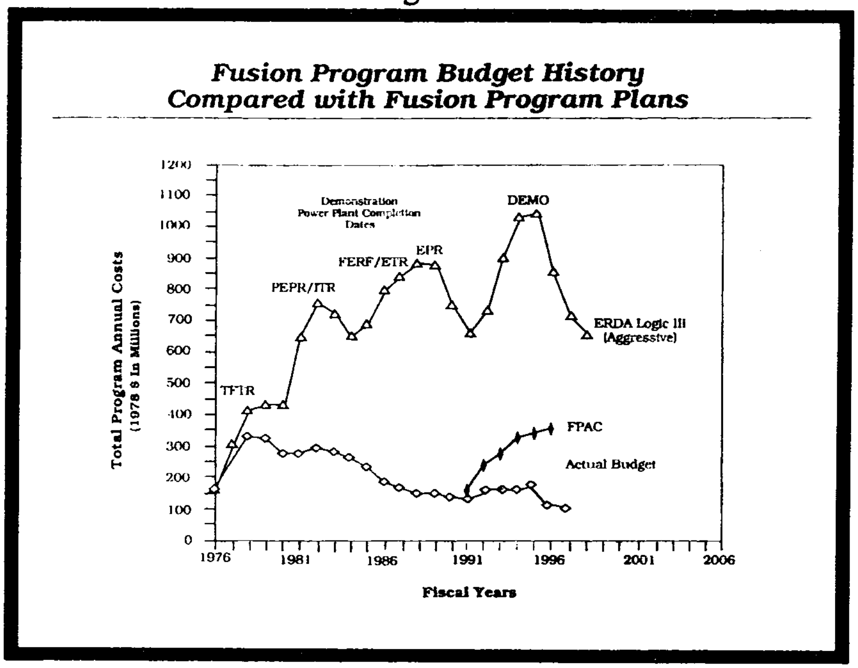


Figure 1 shows a plan which was developed by the Fusion Policy Advisory Committee (FPAC), convened by Admiral Watkins when he was Secretary of Energy. At the top of the plan was the Tokamak Physics Experiment (TPX) which would have been a major new U.S. facility with a price tag of $700 million. Also included in this plan were a number of facilities being developed on an international basis, including the International Thermonuclear Experimental Reactor (ITER). At that time, the Department of Energy also identified several other facilities dealing with materials and blanket development that would be needed. All of these efforts would culminate, according to the plan, in a demonstration reactor around the year 2025. Because of the compressed timetable and the need to do many of these projects simultaneously, the budget requirements for reaching a demonstration reactor by the year 2025 were immense—even with many of the projects being done on an international basis.

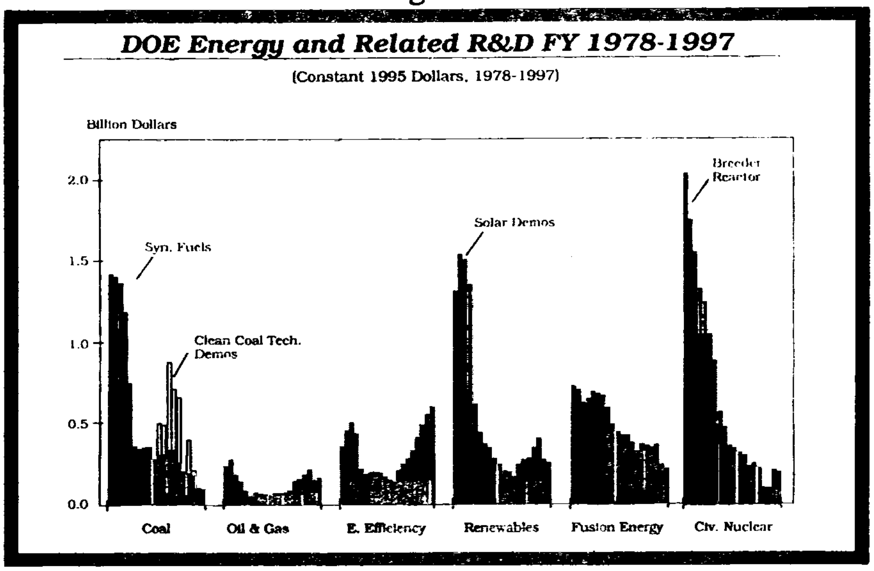
Figure 2 shows the fusion program budget history compared with fusion program plans in FY78 dollars. The budget requirements of the FPAC recommendations caused a doubling of the budget over the five year period form 1992 until 1997, which was impossible to achieve in the budget environment of that period. Also shown are the budget figures for a fairly aggressive fusion program to reach a power reactor.

Figure 2



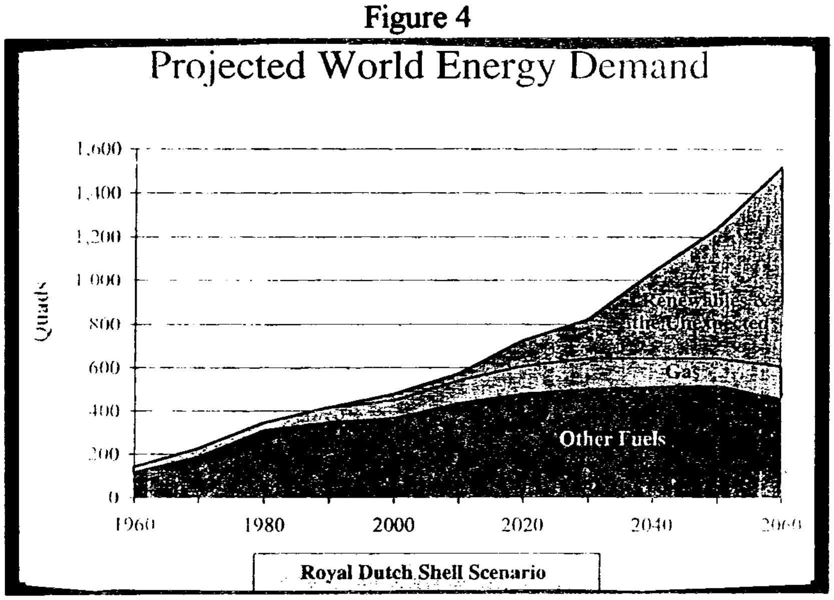
An important factor that has affected the fusion budget is the country's view of energy. Energy is not considered a high-priority issue at this time. Therefore, funding for alternative energy technologies, like fusion, have suffered in recent years. Figure 3 shows funding for various energy technology programs from 1978 to 1997. In 1978, when there was an energy crisis in the United States and there were predictions that natural gas would be in short supply in the near future. There was a big ramp-up in energy research technologies. But as the crisis dissipated, funding for energy technologies declined substantially. There are some anomalies to this trend. For example, funding for clean coal technologies increased despite the general downturn because it was a part of an agreement between the United States and Canada on acid rain.

Figure 3



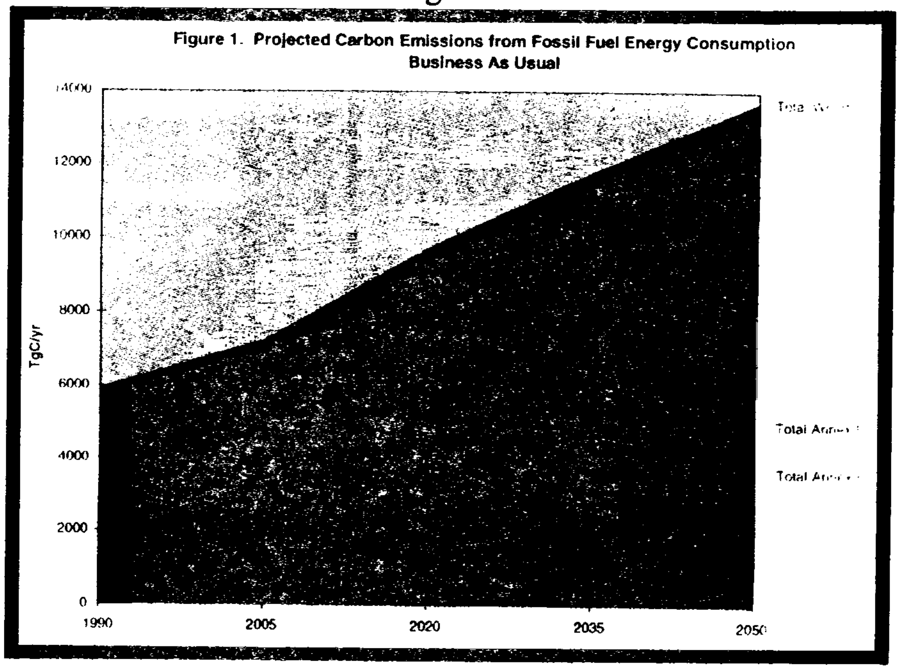
Despite the fact that energy is not currently considered a high priority issue by the American people, energy problems remain. Figure 4 shows a Royal Dutch Shell scenario for projected world demand for energy through the year 2060. Demand is rising far beyond supply. And, Figure 5

Figure 4



shows projections of carbon emissions from fossil fuel energy consumption. Carbon dioxide in the atmosphere is going to go up substantially if we remain on our current path. These two factors alone make a strong argument for investment in fusion research.

Figure 5



A Redirected Program

Figure 6

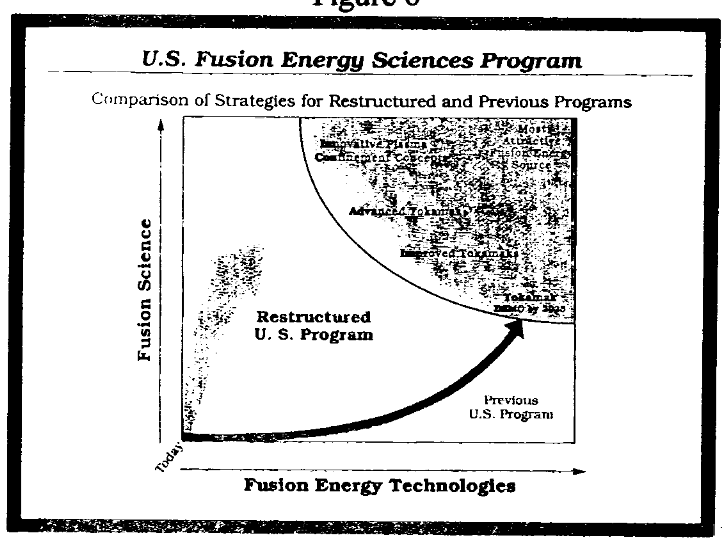
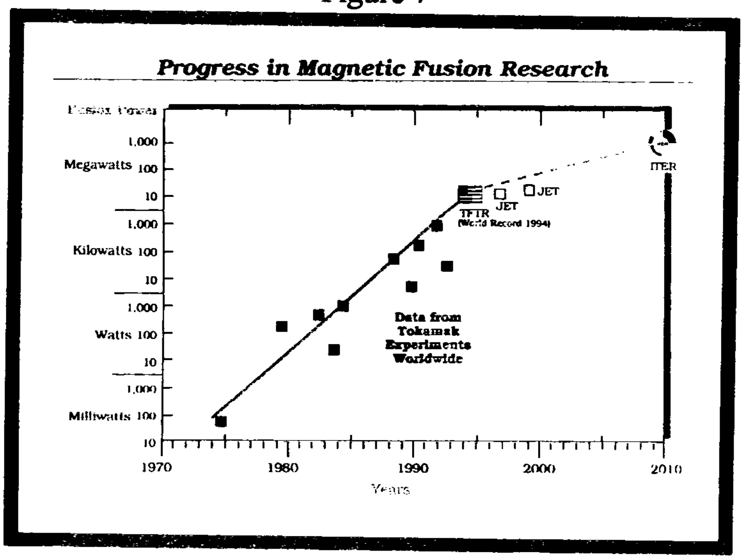


Figure 6 shows schematically the change that the Department of Energy is undergoing in the fusion energy science program. The United States had been on a path leading to a demonstration reactor by 2025. But, in truth, where we really want to get to is the *most attractive fusion energy source*. Where we are headed now highlights the science of fusion energy research, where the objective is to improve our understanding of the science to allow us to have a much better predictive capability to test innovative new concepts. This permits the testing of new concepts without the need to build as many devices as we did with the tokamak program.

Figure 7



Progress in fusion has been dramatic. Figure 7 shows how much fusion power would have been produced if deuterium and tritium had been available in various experiments over the years. It goes from 100 milliwatts in 1970 to 10 megawatts in TFTR. This enormous progress was achieved by building a series of increasingly larger tokamak devices, and also came from an increased understanding of magnetically-confined plasmas. One of the most exciting advances in that regard is our understanding of energy transport in tokamaks. Transport has been a very difficult, and somewhat intractable problem. But the results that have been achieved by the enhanced reverse sheer mode in a number of tokamaks is remarkable. The Department believes that these types of results show that predictive capabilities are improving and can ultimately save time and money in our effort to harness fusion energy.

The new mission statement for the program is to advance plasma science, fusion science, and fusion technology to develop the knowledge base for an economically and environmentally attractive energy source for the nation and the world. The vision for the program is in three parts:

- Understanding the physics of plasmas, the fourth state of matter
- Identifying and exploring innovative and cost-effective development paths to fusion energy

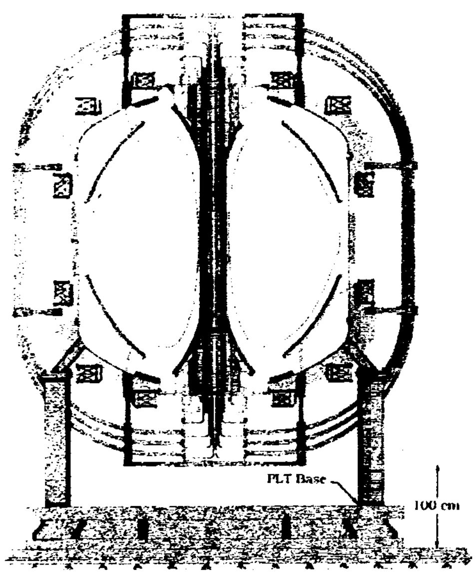
- Exploring the science and technology of burning plasmas—the next frontier in fusion research—as a partner in an international effort.

I believe that with this restructured program, the United States can be an active and desirable international partner.

The program goals focus on innovation and science. The Department has initiated a modest basic plasma science program. The objective of the program is to increase the scientific productivity of existing facilities such as DIII-D at General Atomics in San Diego and Alcator CMOD at MIT. The Department also hopes to enhance theory and modeling research, and is placing increased emphasis on exploring alternative concepts.

Figure 8

National Spherical Torus Experiment



Features:

- A physics experiment
- Highly efficient containment of plasma energy, ~30-45%
- Self generates up to 90% of confinement current
- Sustains confinement current up to steady-state
- Extremely compact
- Fusion-like plasma at high temperatures

One alternative concept for which the Department is requesting funds in FY 98 is the National Spherical Torus Experiment (NSTX) at Princeton. This configuration (seen in figure 8) shows a lot of promise. It is highly efficient in terms of its confinement of plasma, it has high beta, it self-generates much of its confinement current, it has the potential of steady state operation, and it is an extremely compact configuration. The NSTX experiment is modest in cost at $24 million, and utilizes the existing PPPL infrastructure in terms of diagnostics, power supplies, and the TFTR control room.

Other goals of the redefined U.S. fusion energy program include shutting down TFTR to free up funds for growth in other efforts, enhancing research on radiation-resistant materials, meeting commitments to ITER within constant funding levels, and continuing a minimal inertial fusion energy program in coordination with the Office of Defense Programs in the Department of Energy.

The Department of Energy's fusion program has weathered difficult times and significant reductions, but I think there is tremendous scientific talent in the program, and I believe that the United States will continue to make very important contributions to global fusion research.