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An Accelerated Fusion Power Development Plan[1]

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Energy for electricity and transportation is a national issue with worldwide environmental and political implications. The world must have energy options for the next century that are not vulnerable to possible disruption for technical, environmental, public confidence, or other reasons. Growing concerns about the greenhouse effect and the safety of transporting oil may lead to reduced burning of coal and other fossil fuels, and the incidents at Three Mile Island and Chernobyl, as well as nuclear waste storage problems, have eroded public acceptance of nuclear fission. Meeting future world energy needs will require improvements in energy efficiency and conservation. However, the world will soon need new central station power plants and increasing amounts of fuel for the transportation sector. The use of fossil fuels, and possibly even fission power, will very likely be restricted because of environmental, safety, and, eventually, supply considerations. Time is running out for policymakers. New energy technologies cannot be brought to the marketplace overnight. Decades are required to bring a new energy production technology from conception to full market penetration. With the added urgency to mitigate deleterious environmental effects of energy use, policymakers must act decisively now to establish and support vigorous energy technology development programs. The U.S. has invested $8 billion over the past 40 years in fusion research and development. If the U.S. fusion program proceeds according to its present strategy, an additional 40 years, and more money, will be expended before fusion will provide commercial electricity. Such an extended schedule is neither cost-effective nor technically necessary. It is time to launch a national venture to construct and operate a fusion power pilot plant. Such a plant could be operational within 15 years of a national commitment to proceed.

KEY WORDS: Fusion; energy.

1. INTRODUCTION

The pace of federal energy research and development activities has slowed considerably since the 1970's energy crisis. Once-vigorous energy programs have been cut to subcritical funding levels because low oil prices and surplus energy supplies during the 1980's have created a false sense of energy security.

However, the current energy supply glut will certainly disappear by the mid-1990's, as will excess conversion and distribution capacity.[(1)] The U.S. and the world will once again face energy shortages. Fuel prices will be driven upward by diminishing fossil fuel reserves, atmospheric pollution and greenhouse gas emission reduction measures, and inadequate generating capacity. Energy supply pressures will increase worldwide as the less-developed nations industrialize and the global population continues to rise.

Fusion is one of the most promising future energy technologies. Electricity production is expected to be the

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largest application of fusion power; however, it will have other important applications as well, such as the production of hydrogen and synthetic fuels for transportation.[2–4] Fusion could thus prove as vital to the transportation sector as to the electric utilities. Fusion is an inexhaustible, nonpolluting energy source. Its basic fuel, deuterium, is found in water. The fusion process itself is clean: It leaves no polluting byproducts or radioactive "ashes" behind and is inherently safe. Fusion does rely on a nuclear process, but there is no possibility of a "runaway" or "meltdown" accident. Although some of the internal structure of a fusion reactor will become radioactive, fusion power plants pose fewer radioactive environmental hazards than do conventional nuclear plants.[2–5] These limited radioactive hazards can be further substantially reduced by use of improved and/or new "low activation" materials and by eventual use of fuels that will produce a minimum number of neutrons, thereby minimizing the amount of radioactivity produced in the reactor structure.[6] Examples of such fuel cycles are either pure deuterium (the heavy isotope of hydrogen abundant in all forms of water) or a mixture of deuterium and a helium isotope.

Initially, fusion fuel will likely be a mixture of deuterium and tritium, another form of heavy hydrogen, because deuterium–tritium fuel is the easiest mixture to fuse. Tritium is produced from lithium (a nonradioactive metal). Although not as abundant as deuterium, lithium supplies are adequate to provide for world energy needs for millions of years, and we will have developed the technology to fuse the low-neutron-producing "advanced fuels" long before then.

Recent fusion power plant conceptual design studies indicate that fusion plants using deuterium–tritium fuel should have superior safety and environmental characteristics with respect to both fission and coal technologies, and that fusion power plants could also compete economically with fission and coal-fired plants.[2,5,7]

The prospects for fusion are excellent. The readiness of the fusion program to undertake accelerated engineering development is based on years of steady progress (as shown in Fig. 1). Much of the technology base required for a fusion reactor has been developed in the process of building magnetic fusion facilities such as TFTR (in the U.S.), JET (in Europe), and JT-60 (in Japan), and in building inertial fusion facilities such as NOVA (in the U.S.) and GEKKO (in Japan). The nuclear technology required for a fusion reactor must be developed substantially, but solid technological groundwork has been laid.

Both the public and industry would benefit from a new strategy that expedites the achievement of commercial fusion power:

- Implementation of the Accelerated Fusion Power Development Initiative would provide technical choices for the new power plants that will have to be built during the first half of the twenty-first century (an estimated $5 trillion capital market).
- An accelerated program would expedite the "return on investment" to the public for the past 40 years of fusion research.
- Studies have shown that the total integrated cost of developing and delivering fusion power will decrease sharply if the development pace of the program is accelerated.[27]
- An aggressive program would have the additional benefit of giving the fusion technical community an enhanced sense of purpose and renewed dedication that would spur innovation and accomplishment.
- A vigorous fusion development project would provide competition to other energy technologies.
- Most important, a 15-year schedule for a fusion pilot plant schedule would give the public a nonpolluting, safe energy option soon, when we will need it.

To accomplish this task, however, will require a commitment to the kind of national venture that put a man on the moon.

2. PROPOSED FUSION PILOT PLANT DEVELOPMENT INITIATIVE

2.1. Goal and Purpose

The goal of our proposed accelerated development plan is to construct and operate a fusion pilot plant that generates electricity. The purpose of the pilot plant is to demonstrate the viability of fusion as a practical energy source.

2.2. Objectives

To meet its goal and fulfill its purpose, the pilot plant project must accomplish the following objectives: Identify an affordable, buildable design; develop required components and materials; demonstrate reliability and maintainability in a utility environment; demonstrate

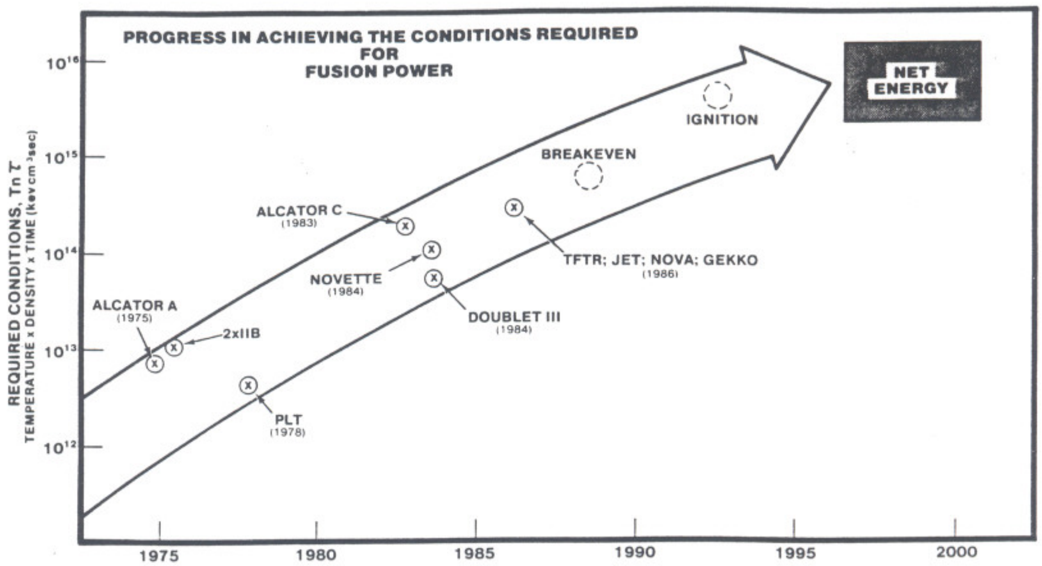

Fig. 1. Fusion progress: The improvement in plasma parameters of ion temperature (T) density (n), and confinement time (τ), often expressed as the product Tn, can be linked with the operation of new experimental facilities. The improvement required for a power plant compared with today's values is no greater than the improvement made in the past 15 years.

safety and environmental acceptability, and provide the technical basis for commercialization.

2.3. Desired Characteristics

The detailed design of the pilot plant must emerge from concentrated design efforts, combined with assessment and R&D on both physics and technology. However, certain general desired characteristics can be identified to guide the effort. These are summarized in Table I.

The pilot plant should have minimum capital cost and minimum thermal power. It need not (probably will not) have a low cost of electricity because this would require a larger size, hence larger capital cost. It should, however, provide data that would allow analyses of the projected cost of electricity for a commercial plant.

The pilot plant should be designed for high availability for prolonged periods of time to demonstrate the practicality of fusion in a utility environment. However, to keep development and capital costs down, construction schedules short, and in recognition of the developmental nature of the facility, it should not be designed for long life. Probably a few full-power years of operational life would be the design goal.

The plant should operate with a high (>10) ratio of fusion power generated to electrical power input. The recirculating power should allow about 100 MW of net electrical power.

The pilot plant should be built of reduced-activation, e.g., ferritic steel, materials,[8-11] keeping in mind realistic expectations of the availability of improved materials consistent with the proposed project schedule.

Safety considerations should be a high priority for the pilot plant,[5] both to help demonstrate the safety features of fusion and to protect the investment in the pilot plant.

To ensure that the goals of the project are realized, the plant must contain adequate design margins in both physics and technology. In the early phases, parallel designs of several concepts should be evaluated. Among these are tokamaks using super-high-field, supercon-

Table I. Desirable Features of a Fusion Pilot Plant

- Minimum capital cost and minimum thermal power
- Net electrical power production of about 100 MW
- Operation at high availabilities (>50%) for prolonged periods
- A high (>10) ratio of fusion power generated to electrical power input.
- Use of reduced-activation materials consistent with project schedule

ducting magnets,[12,13] the possible use of advanced magnetic topologies, such as spherical torus,[14,15] second-stability toroids,[16] and reversed field pinches,[17] and inertial confinement concepts.[18]

Although the main emphasis would be on established approaches, the pilot plant project would initially also investigate some highly speculative concepts with large potential benefits.

The use of advanced technologies and materials would be vigorously pursued in the R&D program, that is, the pilot plant design should not settle for today's technologies and materials but should be a forcing function for the development of new commercial technologies.

2.4. Required Magnetic Fusion Research and Development

Success of the pilot plant project will require enhancement of the base magnetic fusion program as well as initiation of project-specific R&D. These are summarized in Table II and discussed in the following sections.

2.4.1. Base Program Enhancement Areas

2.4.1.1. Energy Confinement Experiments and Theory. Energy confinement experiments and theory will have a strong impact on the pilot-plant parameters, e.g., plasma size, shape, current, and magnetic field. It is important to obtain experimental information in regimes that are as close as possible to the regime of operation of the pilot plant. Theoretical understanding is needed to make more reliable predictions. Knowledge of the dependence of plasma energy and particle confinement upon plasma size/shape, profiles, degree of ohmic heating, auxiliary heating, and alpha power self-heating in reactor-relevant regimes is needed, particularly for different aspect ratios.

2.4.1.2. Steady-State, Current-Drive Experiments. It is highly advantageous to operate fusion reactors in a steady-state mode. Tokamaks and reversed field pinches require special current-drive techniques to operate in this mode. Use of high-energy neutral-particle beams, radiofrequency sources, and possibly other techniques to drive current without prohibitively large power requirements must be thoroughly explored. Self-generated "bootstrap" currents should also be studied as a means to alleviate these external current-drive schemes. Experimental conditions should be as close as possible to those of a fusion pilot plant.

2.4.1.3. Tokamak Configuration Optimization Experiments.

High-Field Tokamak Experiments. High magnetic field operation has provided high plasma performance (*n*-Tau values) in relatively small, ohmically-heated plasmas at high plasma densities. Studies of high-density, high-field plasmas in which auxiliary heating is used to obtain higher temperatures are important for projecting reactor performance. It is also important to determine whether very strong ohmic heating with super-high field operation can be used as a means to reduce greatly, or possibly eliminate auxiliary heating power requirements and to reach ignition conditions more effectively. Auxiliary heating, at some level, will accompany most current-drive schemes, however.

High-Beta Toroidal Experiments. High values of beta, the ratio of plasma pressure to magnetic field pressure and a useful measure of magnetic field and magnet utilization, can improve reactor performance and reduce cost. A particularly attractive approach is the "second-stability" regime, where very high betas might be obtained with relatively low plasma currents and confining magnetic fields. A variety of second stability experiments should be undertaken. Particular emphasis should be given to experiments in reactor-relevant regimes.

High-Aspect-Ratio Tokamak Experiments. High aspect ratio ($A \geq 4$) tokamak designs facilitate use of super-high magnetic fields. Potential advantages include improved confinement, reduced physical size and output power, ability to operate well within stability limits, and reduced plasma-current and (hence) current-drive re-

Table II. Required Magnetic Fusion R&D Enhancement Areas

1. Base program enhancement areas
   a. Energy confinement experiments and theory
   b. Steady-state current-drive experiments
   c. Tokamak configuration optimization experiments
      High field
      High beta
      High-aspect ratio
      Spherical torus
   d. Short pulse D-T burning plasma experiment
2. Project-specific R&D
   a. High-strength structural materials and high-field magnets
   b. Reduced-activation structural materials
   c. High-heat-flux and impurity-control components
   d. Tritium-breeding blankets
   e. Plasma-heating, current-drive, and fueling systems
   f. Remote maintenance equipment and robotics
   g. Steady-state or long-pulse hydrogen experiment, prototypical of pilot plant plasma core

quirements. High aspect ratio can also be useful for second-stabiilty operation. The advantages of second-stability operation and high-field capability could be combined in a high-aspect-ratio machine, thereby allowing overall power densities and wall loadings dictated by minimum cost and/or optimum safety considerations. A key issue is the understanding of thermal transport in high aspect ratio tokamaks, the database for which is non-existent.

Spherical Torus Experiments. The spherical torus, which has a very low aspect ratio (ratio of tokamak major radius to minor radius), has the potential of providing a very compact device since very high first-stability betas are possible. Experiments should be performed to determine plasma confinement and stability properties in the very low aspect ratio, low magnetic field regime. A key issue is the ability to drive large currents that naturally accompany low aspect ratio tokamak operation; current-drive experiments in the spherical torus configuration are a crucial aspect in determining its potential.

2.4.1.4. Reversed Field Pinch. The reversed field pinch (RFP) configuration is, like the tokamak, an axisymmetric toroidal configuration, but the plasma confinement is provided primarily by magnetic fields generated by strong currents flowing within the plasma, rather than in massive external conductors. The reduced magnetic requirements, its high aspect ratio configuration, and its strong ohmic heating (auxiliary heating is not required), combine with the high beta plasma confinement to give special promise for a simplified commercial end-product. The increased plasma turbulence that accompanies the maintenance of the RFP magnetic field configuration leads to reduced confinement compared to a tokamak of comparable current and size (but higher field), and transport represents a key issue for the RFP and will be addressed by a number of devices presently being constructed.

2.4.1.5. Short-Pulse, DT-Burning Plasma Experiment. Plasma confinement during largely self-heated operation must be studied. The proposed Compact Ignition Tokamak would study plasma operation where most of the plasma heating is produced by the fusion reaction products themselves. Another important aspect of a short-pulse, DT-burning plasma experiment is the development of techniques to control the plasma burn.

2.4.2. Project-Specific R&D

2.4.2.1. High-Strength Structural Materials and High-Field Superconducting Magnets. Advances in high-field magnet technology will require high-strength structural materials to accommodate the large forces produced by the magnetic fields. Advanced steels, titanium, and composite materials would be investigated and developed to handle high stress levels. Filamentary niobium-tin superconducting material would be developed to provide magnetic fields of 18 Tesla or more at the coil. Niobium-aluminum and niobium-aluminum-germanium superconducting materials, for which short samples exist, would be developed for use in higher-field magnets.

2.4.2.2. Reduced-Activation Structural Materials. Reduced-activation materials[8–11] should be used in the neutron environment of the pilot plant wherever possible (consistent with expected development schedules for improved materials and the pilot plant schedule). Improved stainless steels of both the austenitic and ferritic types would be the strongest candidates for structural materials, although other materials would also be considered. Emphasis would also be given to reduced-activation candidate materials for other functions, e.g., tritium breeding and high heat flux components. The primary intent is for the pilot plant to be a forcing function for improved materials for commercial applications.

2.4.2.3. High-Heat Flux and Impurity-Control Components. Improved concepts for handling the energy and particle outflow of the plasma should be developed. Improved divertor concepts based on very low edge-plasma temperatures or renewable surfaces, e.g., liquid metals, *in situ* beryllium plasma spray, solid balls, etc., should be pursued. The possible application of simpler pumped limiters to replace divertors should also be included. Special attention would be given to disruption control in tokamaks. In addition, mechanisms for rapid, safe termination of the plasma would be developed.

2.4.2.4. Tritium-Breeding Blankets. Tritium-breeding blankets with the following characteristics would be developed: a net tritium breeding ratio of above unity, extrapolation to commercial power reactors, and good safety/environmental performance. Primary options are self-cooled, liquid-metal blankets and helium-cooled, solid-breeder blankets. Lithium-bearing molten salts should also be pursued.

2.4.2.5. Plasma-Heating, Current-Drive, and Fueling Systems. Improved plasma-heating and current-drive options are required, particularly with respect to efficiency and cost. The primary options are ion-cyclotron heating (ICH) fast waves, lower hybrid (LH) waves, electron-cyclotron heating (ECH), and negative-ion-based neutral beams. Lower hybrid heating and ECH will likely be used for profile control of the plasma temperature and pressure. The primary issue for ICH and LH is the compatibility of the launching structure with plasma edge conditions. For ECH, higher power, high-frequency technology via gyrotrons or free-electron lasers are required. The issue for neutral beams (NBI) is a scale-up in energy to above 1 MeV. Typically, LH would be used to drive current in the outer plasma for either NBI or ICRH inner plasma current drive. Folded wave guides for the fast-wave drive should be used. Negative ion NBI will require either RFQ or ESQ acceleration. In any event, significant bootstrap current (>30%) would be highly desirable.

A more exotic approach, helicity-injection current drive, if proven in time, would substantially enhance the ability of steady-state current drive. Either dc or ac helicity injection is a strong possibility for the RFP and may also be possible for the spherical torus, where the poloidal field on the outboard side of the torus is comparable to, if not higher than the toroidal field in this low aspect ratio tokamak. High-speed fueling techniques will also be required. Techniques such as multi-stage gas guns, electron-beam-driven pellets, and plasmoid injection are prime examples.

2.4.2.6. Remote Maintenance Equipment and Robotics. R&D on improved remote maintenance systems and components will be required. Special attention would be focused on repair/replacement of key in-vessel components such as divertor plates. Maximum use would be made of advanced robotics. State-of-the-art computer simulations would play a key role.

2.4.2.7. Hydrogen Experiments Prototypical of Pilot Plant Plasma Core. A steady-state or long-pulse hydrogen experiment should be initiated to study impurity control, heat removal, steady-state current drive, and plasma control for long periods of time. This experiment would complement the short-pulse, DT-burning plasma experiments such as CIT. Another goal of the hydrogen experiment could be to test advanced superconducting magnet technology. It would also test other technologies (heat-removal systems, heating systems) that would be used in the pilot plant.

2.5. Required Inertial Fusion Research and Development

In addition to the base DOE inertial fusion program,[29] enhanced, project-specific R&D efforts will be required. These are summarized in Table III and discussed in the following sections.

Table III. Required Inertial Fusion Enhancement Areas

- Systems design of commercial power plants
- Development of high-efficiency, repetitively-pulsed drivers
- Development of power plant components and subsystems
- Development of fuel pellet manufacturing capabilities

2.5.1. Systems Designs of Commercial Power Plants

Limited effort has been devoted in the past to conceptual designs of inertial fusion commercial power plants.[18,21,22] If an inertial fusion pilot plant project is to be considered within the time frame of this plan, a wide variety of design options must be explored on an urgent basis.

2.5.2. Development of High-Efficiency, Repetitively Pulsed Drivers

Inertial fusion experiments to date are based on single-pulse laser and particle-beam technologies. In addition, no individual laser technology presently has all the required characteristics (for example, efficiency) that would be required in a commercial power plant. An ambitious technology development effort is required to develop the necessary driver characteristics required for commercial applications.

2.5.3. Development of Power Plant Components and Subsystems

Although inertial fusion power plants could make use of some of the materials and nuclear technology developed for magnetic systems, they require a number of unique subsystems that have not yet been fully demonstrated. These subsystems, some of which have been partially conceptualized, include wetted-wall technologies, pellet-positioning systems, and optics protection systems.

2.5.4. Development of Fuel-Pellet Manufacturing Capabilities

Power plant economics requires that fuel pellets be mass produced cheaply. It will be necessary to manufacture the pellets *in situ* as an integrated part of the power plant. Techniques for accomplishing this task must be invented and demonstrated.

2.6. Management Approach

The fusion pilot plant project will require strong and imaginative leadership. The management structure could take any of several possible forms. Two possible types of organizations have been successfully used in the past, especially by the Department of Defense.

One management structure could take the form of a congressionally chartered, nonprofit systems engineering and management corporation (the "Fusion Development Corporation"), to act as agent for the government in managing the project. The Department of Energy could oversee the corporation, or it could be accountable directly to Congress. The Fusion Development Corporation would then be responsible for all aspects of the project, to include competitive bidding for all components and subsystems, timely narrowing of options, and focusing of effort to meet the project schedule. The corporation would competitively select subcontractors as required and would encourage the formation of industry/laboratory/university teams to perform necessary R&D, as appropriate.

Another possible management structure would have the Department of Energy competitively select a prime contractor to manage the project. The Naval Reactors Program[19] provides a good model for the Department of Energy to consider, one in which two competing prime contractors are maintained for conceptual design and engineering.

Whatever the form of top-level management structure, the project managers would identify the science and technology support programs, beyond the existing fusion base R&D program, needed to build the pilot plant. Project personnel would make use of past and current fusion reactor studies[6,12–18,20–22] and planning documents[23-28] as well as the approaches taken to accomplish similar goals in other programs, (e.g., naval reactor, space, fission power, and defense).

As conceptual design proceeds, project-specific R&D tasks would be identified and funded. Industries, laboratories, and universities would participate in the R&D, both separately and as teams, as appropriate.

The pilot plant project will require data from both a generic R&D program and project-specific R&D, as illustrated in Fig. 2. This figure shows the three foundation elements for a national venture to achieve commercial fusion power: (1) an enhanced base fusion R&D program that consists of a broad set of physics and technology programs that develop understanding of the fusion process and advance the state of the art in fusion technology, (2) the pilot plant project, and (3) project-specific R&D programs. The project-specific R&D programs would develop data required for the pilot plant design and the technologies required for its construction. Eventually, this element would perform a similar function for the subsystems required for commercial fusion applications.

As the pilot plant moves into construction, the generic R&D program would continue to emphasize innovation and concept improvement, and the project-specific R&D activities would re-focus on commercial power plant R&D. The data and experience gained from the activities shown in Fig. 2 would lead to pilot plant operation and complete the technical basis for fusion commercialization.

The proposed accelerated pilot plant project initiative will require aggressive development of advanced materials and technologies that demonstrate the safety and environmental advantages of fusion while respecting costs and schedule. The initiative will also require immediate acceleration of near-term physics programs required for reactor design optimization.

Because the plan is an ambitious one that is based on symbiotic advances in both physics and technology on a tight time schedule, it entails considerable technical risk. It is proposed to reduce this risk by carrying out several parallel, competing development programs for all critical physics and technology subsystems, including multiple design options, and to require that design margins for both physics and technology subsystems be sufficient to ensure performance in the face of technical uncertainties. Wherever possible, aggressive technology development will be used to add margin against uncertainties in the physics. The risk is controlled by requiring an intense up-front period (7–8 years) of project specific R&D and plant design. If the progress during that time does not lead to the conclusion that the pilot plant would be successful, construction would be delayed until that confidence was achieved. To ensure the participation of, and relevance to the electric utility industry, it is desirable that the pilot plant be constructed at an existing utility site. However, due to licensing issues, it would probably be necessary to locate the project at a government-owned nuclear reservation. Fortunately, there are several such sites with easy access to hookup to a utility grid.

The pilot plant project should be initiated as a National Venture by enabling legislation.

2.7. Schedule and Cost

The proposed pilot plant project schedule is shown in Fig. 2. The schedule is shown in terms of three ele-

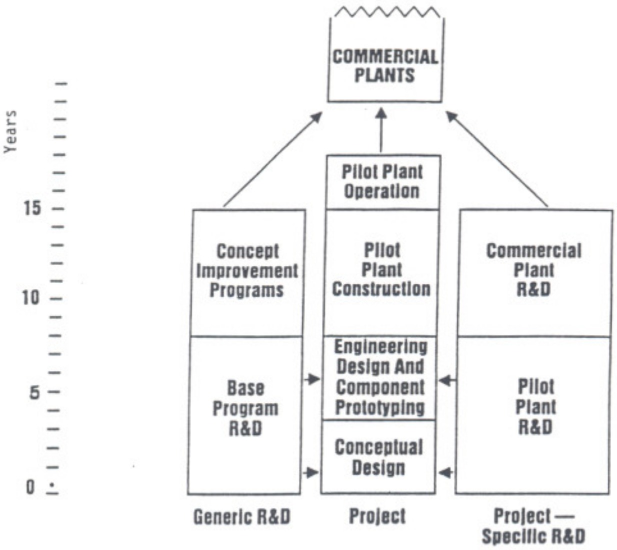

Fig. 2. The data and experience gained from the sum of a generic R&D program, project-specific R&D, and the design, construction, and operation of the pilot plant provide the basis for fusion commercialization.

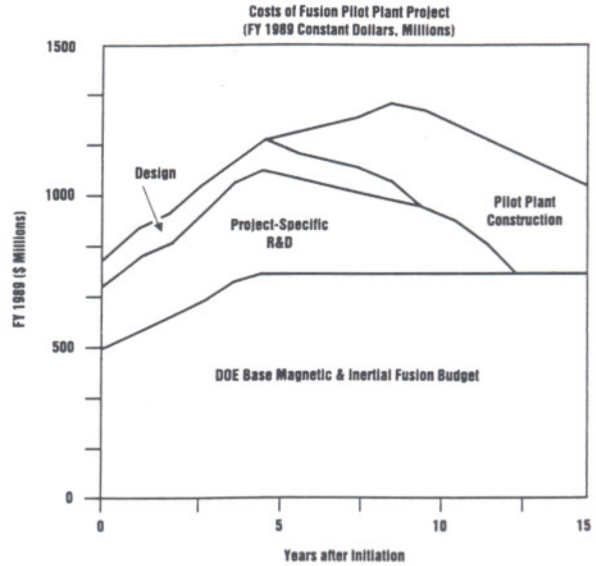

Fig. 3. Estimated cost of the Fusion Power Pilot Plant Initiative. To obtain funds, it is suggested that Congress consider establishing a National Energy Technology Development Trust Fund. Money for the fund could be obtained through a few percent tax on fossil fuel consumption, for the purpose of developing new energy technologies not based on fossil fuels.

ments: generic R&D (left), project-specific R&D (right), and pilot plant project (center). Generic R&D would provide data from the base program during the conceptual design phase (about 3 years) and would continue into the engineering design and prototyping phase until the engineering design is frozen (about 8 years into the project). Project-specific R&D would provide design data and component development to the design, including prototype testing, leading eventually to manufacture. Actual construction is estimated to take 7 years. The estimated cost (FY 1989), based in part on update to earlier planning studies[23,27] is shown in Fig. 3.

Design and project engineering work will be about \$100 million per year over 8 years. Pilot plant construction is assumed to cost about \$2 billion and to take 7 years.

The costs above the base program, associated with project-specific R&D for the pilot plant, are estimated to average \$200–300 million per year. These costs would be more accurately estimated as a conceptual design of the pilot plant and a detailed R&D plan are developed. We can, nevertheless, identify some of the major components of the required R&D: (1) steady-state or long-pulse hydrogen tests (\$25–50 million/yr); (2) materials and nuclear technology (\$25–50 million/yr), and (3) magnet, heating, and fueling technology (\$25–50 million/yr). The base program would need to grow over 5 years to about 50% above its current subcritical level and would emphasize basic physics experiments, concept improvement tests, theory, and long-term technology development. Enhancement funds would be needed in: (1) short-pulse ignition tests (\$50–100 million/yr); and (2) supporting physics experiments (\$25–50 million/yr). U.S. participation in international projects, such as ITER, would be supported by the base program. Inertial fusion construction projects for weapons applications, such as the Laboratory Microfusion Facility, would be funded separately by the defense program budgets.

2.8. Financing

The initiative proposed here could be funded as a part of the normal government budgeting process. However, the federal budget deficit and the need to proceed with a number of other (currently unfunded) large national projects suggests consideration of an alternative.

Because fossil fuels are a scarce resource, it is appropriate that the current economics of fossil fuel use should include a "set-aside" to develop technologies that will reduce or eliminate our dependence on fossil fuel technologies in the future.

Thus, consideration should be given to the congressional establishment of a National Energy Technology

Development Trust Fund. Money for the fund could be obtained by a tax on fossil fuel consumption. Use of monies from this fund would be restricted to the support of new, long-range energy technologies with the potential for reducing our dependence on fossil fuels. Fusion would be only one of several technologies developed from this fund. Large R&D tax credits could be given to companies willing to invest corporate funds to develop technologies aimed at replacing fossil fuels.

2.9. Conclusion

A fusion power plant could be constructed, within 15 years of a commitment to proceed, provided that a vigorous engineering and technology development effort is established. Strong, imaginative leadership will be required. The cost of such an effort is estimated to require R&D funds of $300–500 million a year as a supplement to the current base fusion budget and additional funds later for pilot plant construction. The base fusion budget also requires enhancement of about 50% over the current level.

Implementing this initiative would benefit both the public and industry in the following ways:

- Implementation of the Accelerated Fusion Power Development Initiative would provide technical choices for the new power plants that will have to be built during the first half of the twenty-first century (an estimated $5 trillion capital market).
- An accelerated program would expedite the "return on investment" to the public for the past 40 years of fusion research.
- The total integrated cost of developing and delivering fusion power will decrease sharply if the development pace of the program is accelerated.[27]
- An aggressive program would have the additional benefit of giving the fusion technical community an enhanced sense of purpose and renewed dedication that would spur innovation and accomplishment.
- A vigorous fusion development project would provide competition to other energy technologies.
- Most important, a 15-year fusion pilot plant schedule would give the public a nonpolluting, safe energy option soon, when we will need it.

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