Criteria for Practical Fusion Power Systems

Report from the EPRI Fusion Panel

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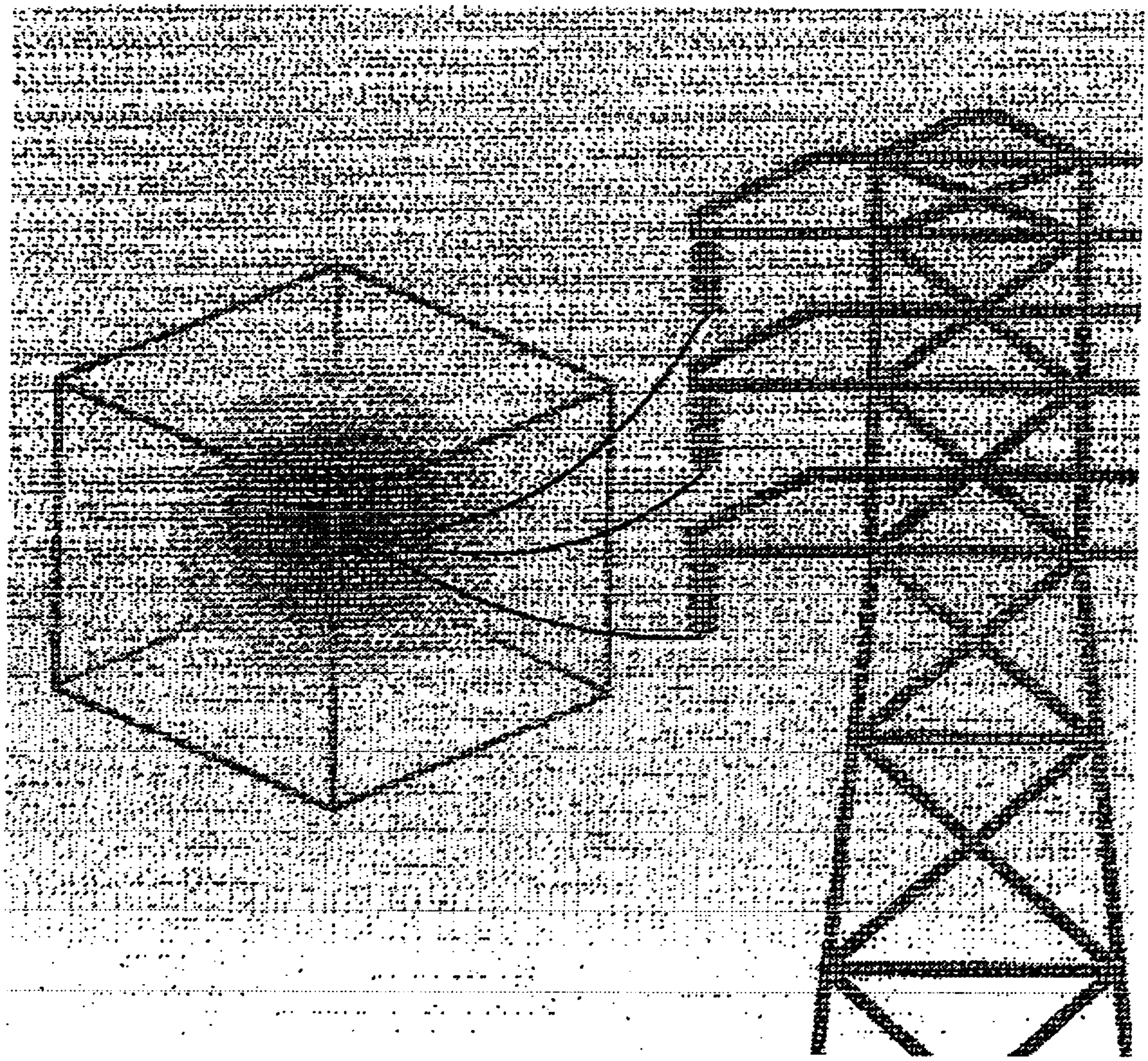

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Letter from EPRI Panel Chairman

August 29, 1994

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 last 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.

Fusion's ultimate commercial appeal will depend on a number of factors. As the technology is developed and refined, a vision of fusion power plant buyer requirements is essential to providing a marketable product. The guidelines presented in this brief report—which reflect the views of an EPRI panel of experts selected for their industry experience and insights on managing the introduction of major new power generation technologies—are a first attempt toward building that vision. They cover the broad range of realities that fusion power developers must face in implementing and commercializing this new technology.

I hope and believe that the group's collective vision, as described in these guidelines, will be helpful in beginning to build a framework of design, regulation, and operational specifications for fusion power's expeditious evolution and successful adoption.

Jack Kaslow
EPRI Fusion Panel Chairman

For over four decades, researchers have been working to tap the essentially infinite power of fusion—the fundamental energy source in the universe. Advances in recent years are promising: In late 1993, experiments at the Princeton Plasma Physics Laboratory achieved large-scale thermal power production from fusion in the laboratory. For many, these results reasonably demonstrate the scientific feasibility of fusion power.

Development of practical fusion power systems is still years away. Yet early awareness of what will be required in an eventual real-world application can help ensure that crucial applications issues are addressed as the technology develops, thereby contributing to the speed and economy of the development process. To that end, the EPRI Fusion Working Group—composed of present and former utility industry executives—has identified criteria to help guide the work of fusion developers toward practical power systems that can obtain the financial, public, and regulatory support needed for implementation. Special attention was given to selection of criteria that are likely to prove timeless as power markets evolve in the decades ahead.

This brief report augments and expands on two earlier EPRI publications with somewhat differing but complementary perspectives:

> *Report of the 1992 Fusion Panel*, TR-101649, November 1992
> ...expert panel's key criteria for comparing alternative fusion technologies
>
> *Utility Requirements for Fusion*, AP-2254, February 1982
> ...broad-based industry derivation of fusion power plant characteristics judged most important to electric utilities

Both of these earlier EPRI publications are recommended as basic references on transferring fusion technology from the laboratory into practical power systems. This third report adds a new dimension: assuring the necessary financial, public, and regulatory approvals of fusion power plant technology.

Three Principal Types of Criteria

In a thorough review of practical fusion power system characteristics, three criterion groups of overarching importance emerged:

1 ***Economic*** **2** ***Public Acceptance*** **3** ***Regulatory Simplicity***

Each of these principal topics encompasses a number of more specific criteria and parameters that together describe the requirements. It is not practical to assign values to these criteria for two reasons. First—because the world of tomorrow will be different—social, regulatory, and energy issues will pose moving targets. Second, there are potential tradeoffs among many of the factors. Yet these criteria are likely to remain crucial to the successful deployment of fusion power plants. The following sections discuss the criteria and parameters in greater detail, providing a critical "reality checklist" for developers of fusion technology concepts.

Economics

Future fusion power plants must present favorable economics. To achieve this goal, the plant must meet a number of criteria.

- To compensate for the higher economic risks associated with new technologies, fusion plants must have lower life-cycle costs than competing proven technologies available at the time of commercialization.

  Life-cycle costs are made up of a number of components, including capital, fuel, operations and maintenance (O&M), general and administrative (G&A), and end-of-life costs. The following factors can help minimize these costs:
  - Size flexibility, or the ability to build plants in a range of capacities without a cost penalty related to size
  - Low land requirements
  - Rapid and simple construction
  - Design simplicity
  - High reliability
  - High unit availability
  - Long life
  - Low fuel-cycle costs
  - Minimal operating personnel
  - Personnel qualifications similar to those for competing technologies
  - Low end-of-life costs
- The costs for electric system components that are not required for competing technologies must be considered. Such components could include special transmission and power quality equipment
- The ability to finance early fusion plants will require a high level of confidence in the performance of a commercial plant. Convincing validation of performance in demonstration or pilot plants will be needed to gain that confidence.

Public Acceptance

Public acceptance and customer satisfaction will be essential to the commercial success of future fusion power plants. A positive public perception can be best achieved by maximizing fusion power's environmental attractiveness, economy of power production, and safety. Throughout the development process, however, ongoing interaction with the public is critically important, as design choices are fundamental to public acceptance Standards must be high Renewable energy source plants may represent the public's benchmark for environmental cleanliness and safety

- Increasing public concern over environmental impacts and demand for environmental responsibility will play a strong role in the acceptance of fusion power plants. Maximizing environmental attractiveness requires attention to many factors:
  - Radioactive wastes should be avoided or minimized and publicly acceptable waste handling solutions developed.
  - Emissions and inventories of heavy metals, toxic chemicals, and other pollutants that result from plant construction as well as plant and fuel-cycle operations should be as low as possible—and lower than the competition.
  - Waste heat should be minimized, as plant siting and cooling water availability are likely to remain public issues.
  - Sensitivity to the growing conflict between environmentalists and free market forces will be needed, as the outcome of this debate could affect fusion plant design. This will require a good understanding of a variety of relevant issues, such as regulatory economics, politics, technical concerns, and health impacts.
- A positive response to the public interest in fusion power economics will be necessary. This public interest will focus on elements that directly affect consumers:
  - The cost and reliability of power to the end user
  - Impacts of fusion on U.S. global competitiveness—largely determined by fusion power costs, but also by U.S. manufacturing capabilities and the ability to sell fusion plants abroad
- Assuring an accurate public perception of fusion plant safety can help encourage the widespread support this technology will require. Essential activities include:
  - Increasing credibility—an essential ingredient—by encouraging public involvement in setting safety standards and policies
  - Ensuring that the first public experiences with fusion plants are positive
  - Avoiding terminology from existing technologies having negative safety connotations when not relevant to fusion

Regulatory Simplicity

Because fusion is so different from existing fossil and nuclear power generation technologies, existing regulatory requirements for those technologies are not likely to be relevant to fusion. Appropriate regulation for fusion power plants should be determined by characteristics of the technology, the need for an expeditious and efficient regulatory process, and the obligation to minimize unnecessary barriers to fusion development.

- Plant and systems design will influence regulatory requirements. Important directions and considerations include the following:
  - Avoidance of any need for separating the plant from population centers or for off-site emergency planning
  - Minimal need for engineered safety features and administrative controls to protect the public
  - Minimal waste generation, with air and water emissions and solid waste levels lower than those of fossil power plants
  - Waste streams that can be handled easily under regulations in place for existing technologies
  - Operator safety issues no more severe than for existing technologies
  - Minimal of occupational exposure to radiation in plant operation, maintenance, and waste handling activities
- Any permitting/licensing process for fusion power plants should be designed to allow issuance of permits/licenses prior to major capital commitment and for the life of the plant.
- Public acceptance of fusion power technology will also affect the level of regulation of fusion power. Public education through continuing and open access to information should be a high priority during fusion development and commercialization.

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