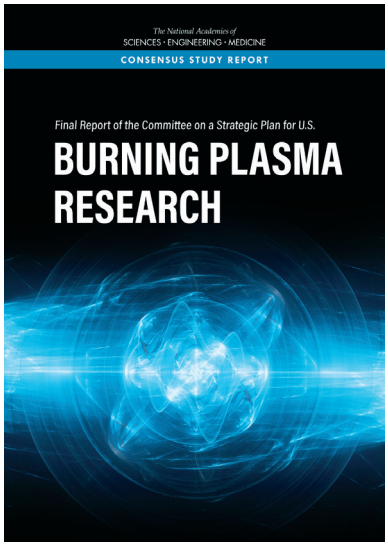
Consensus Study Report
HIGHLIGHTS
December 2018

Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research



Fusion offers the prospect of virtually unlimited energy. Magnetic fusion experiments confine ionized gas, called plasma, at temperatures found in the heart of a star in order to fuse hydrogen into helium. This process releases large amounts of energy in the form of energetic particles that can be harnessed to create electricity while sustaining the energy-producing plasma. The United States and many nations around the world have made enormous progress toward achieving fusion energy. Many of the complex physical processes of magnetically confined plasma are now understood, and the first construction phase of the international ITER fusion reactor is more than half complete.

With ITER scheduled to go online within a decade and demonstrate controlled fusion ten years later, ***now is the right time for the United States to develop plans to benefit from its investment in burning plasma research and take steps to develop fusion electricity for the nation's future energy needs***. At the request of the Department of Energy, the National Academies of Sciences, Engineering, and Medicine organized a committee to develop a strategic plan for U.S. fusion research.

The final report's two main recommendations are:

- The United States should remain an ITER partner as the most cost-effective way to gain experience with a burning plasma at the scale of a power plant.
- The United States should start a national program of accompanying research and technology leading to the construction of a compact pilot plant that produces electricity from fusion at the lowest possible capital cost.

Aerial photograph of the ITER site. *Construction began in 2010 after site preparatory work. By December 2017, more than half of ITER total construction work through first plasma was complete. On June 2018, ITER construction continues on track having achieved all 33 Council-approved project milestones scheduled since January 2016.*

ABOUT ITER

ITER is a burning plasma experiment and the critical next step in the development of fusion energy. The experiment will help answer key science questions and test critical methods for controlling plasma in order to extract electricity-producing heat. ITER is a large and ambitious project that integrates multiple advanced technologies and combines the scientific and engineering expertise, industrial capacity, and financial resources of many nations. As a partner, the United States receives full benefit from the technology developed for ITER while providing only a fraction of the financial resources. U.S. industry is building major systems for ITER and thereby gaining expertise in fusion engineering science and building industrial capabilities.

FROM ITER TO FUSION POWER PLANTS

Although the United States provides only part of the cost of ITER, if the United States is to profit from its share of the ITER investment, the nation's strategic plan for fusion should combine its ITER experience with the additional science and engineering research needed to realize reliable and economical fusion electricity. Without this additional research, the United States risks being overtaken as other nations advance the science and technology required to deliver a new and important source of energy.

Recent advances motivate a new national research program with the goal of constructing a compact fusion pilot plant. Scientists can now better control and predict the properties of high-pressure magnetically-confined plasma. New technology, such as high-field superconducting magnets, make possible higher pressure plasma with higher fusion power density. New manufacturing methods give engineers tools to design materials and components that will reliability handle the escaping heat from an energy-producing plasma.

This compact pilot plant would produce power at a similar level to that expected in ITER but in a smaller, less expensive device that would allow net electricity production. Developing a compact device will make fusion affordable and attractive for industrial

participation, and provide the knowledge needed to design the first commercial fusion power systems. By starting now, a U.S. fusion research program can be ready in time to use the knowledge learned from ITER to demonstrate electricity production by mid-century.

U.S. PARTICIPATION IN ITER

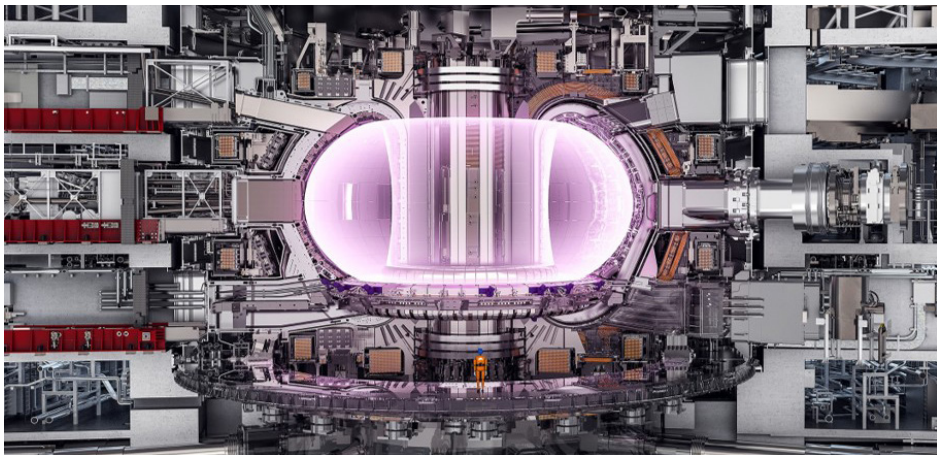
The committee was also tasked to recommend strategic guidance if the United States decides to withdraw from the ITER project. This withdrawal would significantly disrupt the national research effort, isolate U.S. researchers from the international effort, and eliminate the benefit of sharing the cost of producing a burning plasma at the power plant scale. Nevertheless, if the United States decides to withdraw from the ITER project, the report recommends the United States continue research toward the construction of a compact fusion pilot plant. However, without ITER participation, U.S. progress will necessitate a much greater commitment of resources over a longer timeframe, significantly delaying the implementation of fusion energy.

STRATEGIC RESEARCH PLAN

A national program of research and technology leading to the construction of a compact pilot plant at the lowest-possible capital cost will engage universities, national laboratories, and industry in the realization of fusion power. Near- and mid-term research activities recommended by the report's strategic plan are:

- Understand the science, production, and control of a burning plasma with ITER,
- Demonstrate the science and engineering to sustain a magnetically confined plasma with the confinement and power-handling properties needed for a compact fusion pilot plant,
- Advance very high-field superconducting magnets for fusion,
- Expand research in fusion nuclear science, materials science, and tritium and blanket technologies needed to fully enable fusion electricity, and
- Promote promising innovations in burning plasma science and fusion engineering science.

The committee expects that the implementation of its recommendations, including both continued participation in ITER and the start of a national research program for a compact pilot plant, will require additional funding, rising to nearly $200 million beyond the recently enacted annual funding levels. This funding would need be sustained for several decades.



An artist's conception of the ITER experiment when fully constructed.

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