Powering the Future
Fusion & Plasmas

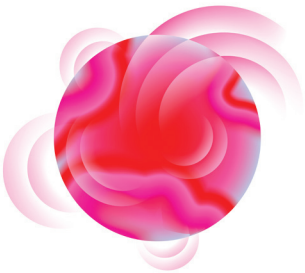
A long-range plan to deliver fusion energy and to advance plasma science

Fusion is the merging of nuclei to release the energy that powers stars; plasmas are ionized gases, the fourth state of matter that makes up stars. The two are inextricably linked. Their shared history exemplifies how basic scientific research translates from a deeper understanding of the universe to technologies that benefit society.

Now is the time to move aggressively toward the deployment of fusion energy, which could substantially power modern society while mitigating climate change. Scientific and technological innovations enable a unique US vision for economically attractive fusion energy, with the goal of a fusion pilot plant (FPP) by the 2040s. Partnership in the international ITER fusion project is essential for US fusion energy development, as is supporting the continued growth of the private sector fusion energy industry that has been seeded with $2 billion of investment over the last decade.

The technological and scientific achievements arising from plasma research are significant and far-reaching. Plasma physics helps us understand not only the confined plasmas that could power an energy-generating fusion reactor, but distant stars and other objects, such as supernovae and black hole accretion disks, that capture our imagination. Understanding the exotic states of matter created using the most intense lasers in the world requires deep knowledge of plasma physics. Plasmas transform society, enabling the development of industry-changing technologies, especially the plasma-enabled manufacturing at the heart of the trillion-dollar information technology industry.

For the first time, scientists have created a long-range plan to accelerate the development of fusion energy and advance plasma science. We speak with one voice in conveying a vision for a vibrant research and development program that will bring significant benefit to society.



Fusion Science and Technology

- Sustain a Burning Plasma. Build the science and technology required to confine and sustain a burning plasma.
- Engineer for Extreme Conditions. Develop the materials required to withstand the extreme environment of a fusion reactor.
- Harness Fusion Power. Engineer the technologies required to breed fusion fuel and to generate electricity in a fusion pilot plant by the 2040s.

Plasma Science and Technology

- Understand the Plasma Universe. Plasmas permeate the universe and are the heart of the most energetic events we observe.
- Strengthen the Foundations. Explore and discover new regimes and exotic states of matter and utilize new experimental capabilities.
- Create Transformative Technologies. Unlock the potential of plasmas to transform society.

Overarching Recommendations

- Align the program with the six technology and science drivers in order to establish the scientific and technical basis for a fusion pilot plant by the 2040s and advance fundamental understanding of plasmas that translates into applications that benefit society.
- Resources for ongoing design and construction of major new experimental facilities should be established in the DOE FES budget.
- Opportunities should be provided for developing new experimental capabilities at a range of scales, as appropriate to address the goals of this strategic plan.
- This long-range planning process, including a strong community-led component, should be repeated no later than every five years in order to update the strategic plan.
- Maturation of preconceptual designs, scope, and costing for proposed new experimental facilities should be part of regular program activities.
- Expand existing and establish new public–private partnership programs to leverage capabilities, reduce cost, and accelerate the commercialization of fusion power and plasma technologies.
- Explore and implement mechanisms for formal coordination between funding agencies that support fusion and plasma science research.
- DOE and FES should develop and implement plans to increase diversity, equity, and inclusion (DEI) in our community. Done in consultation with DEI experts and in collaboration with other institutions, this should involve the study of workplace climate, policies, and practices, via assessment metrics and standard practices.
- Restore DOE's ability to execute discipline-specific workforce development programs that can help recruit diverse new talent to FES-supported fields of research.

Program and Project Specific Recommendations

Fusion Science and Technology

- Initiate a design effort that engages all stakeholders to establish the technical basis for closing critical gaps for a fusion pilot plant, utilizing and strengthening the world-leading US theory and computation capabilities and engineering design tools.
- Rapidly expand the R&D effort in fusion materials and technology.
- Immediately establish the mission need for an FPNS (Fusion Prototypic Neutron Source) facility to support development of new materials suitable for use in the fusion nuclear environment and pursue design and construction as soon as possible.
- Develop the scientific infrastructure necessary for the study of plasma-materials interactions needed to develop plasma facing components for an FPP by completing the MPEX (Materials Plasma Exposure eXperiment) and additional high-heat flux testing facilities.
- Significantly expand blanket and tritium R&D programs.
- Utilize research operations on DIII-D and NSTX-U, and collaborate with other world-leading facilities, to ensure that FPP design gaps are addressed in a timely manner.
- Ensure full engagement of the US fusion community in ITER by forming an ITER research team that capitalizes on our investment to access a high-gain burning plasma.
- Immediately establish the mission need for an EXCITE (EXhaust and Confinement Integration Tokamak Experiment) facility to close the integrated tokamak and exhaust gap and aggressively pursue design and construction.
- Strengthen the innovative and transformative research program elements that offer promising future opportunities for fusion energy commercialization: stellarators, liquid metal plasma-facing components, IFE, and alternate concepts.

Plasma Science and Technology

- Provide steady support for fundamental plasma science to enable a stream of innovative ideas and talent development that will lay the scientific foundation upon which the next generation of plasma-based technologies can be built.
- Complete the design and construction of MEC-U (Matter in Extreme Conditions Upgrade).
- Establish a plasma-based technology research program focused on translating fundamental scientific findings into societally beneficial applications.
- Coordinate a High-Intensity-Laser Research Initiative in collaboration with relevant DOE offices and other federal agencies.
- Pursue the development of a multi-petawatt laser facility and a high-repetition-rate high-intensity laser facility in the US, in partnership with other federal agencies where possible.
- Support networks to coordinate research and broaden access to state-of-the-art facilities, diagnostics, and computational tools.
- Strengthen support of laboratory-based research relevant to astrophysical and space plasmas through increased programmatic and facility funding as well as expansion of partnership opportunities.

Cross-cutting Recommendations

- Ensure robust support for foundational research activities that underpin all aspects of plasma and fusion science and technology.
- Support research that supplies the fundamental data required to advance fusion energy and plasma science and engineering.