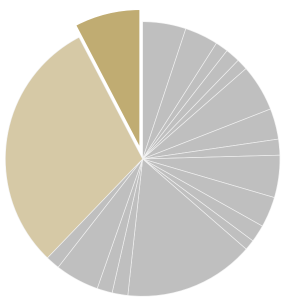
Federal Energy R&D: Fusion Energy Sciences

BY COLIN CUNLIFF AND BATT ODGEREL | MARCH 2020

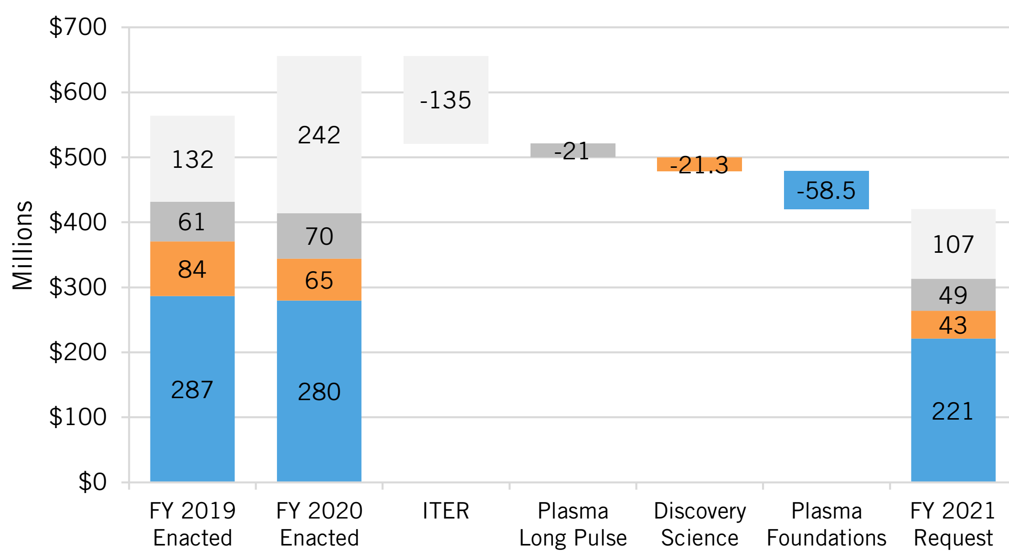
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Fusion Energy (brown)
Basic Energy Science (dark brown)
Energy R&D (light gray)

The mission of the Fusion Energy Sciences (FES) program is to help build the scientific foundation needed to develop a fusion energy source by expanding the fundamental understanding of the physics behind plasmas (i.e., matter at very high temperatures and densities).[1] Comprising 99 percent of the visible universe, plasmas are at the heart of the fusion process that powers the stars.[2] The promise of fusion—an energy system that could generate massive amounts of power using fuel obtained from seawater and earth-abundant materials, with very little pollution—is enormous.

Figure 1: The FY 2021 budget request would cut fusion R&D by 37 percent[3]



What's at Risk

Fusion research and development (R&D) has the potential to contribute to U.S. energy security by making available a robust clean energy technology that relies on widely available and virtually inexhaustible fuel sources. However, the technological advances needed to realize safe, low-cost fusion are still nascent, so basic research into plasma physics—including plasma confinement and plasma-materials interactions—remains essential to advancing toward the goal of fusion energy. Reductions in funding for this program could stall advances in fusion science, while also threatening the United States' leadership in this important area.

Because its science is so wide-ranging, plasma research could spin off a number of applications for other technologies. Advances developed in the quest for fusion energy have already led to the creation of other technologies that provide considerable economic and societal impact, including applications in lighting, semiconductor manufacturing, medical and health science and technology, materials, and waste management.[4] Robust plasma-research funding is therefore necessary to prevent the United States from losing out on future benefits in these and other industries.

Fusion Energy Sciences R&D Activities

R&D in fusion energy is distributed across four subprograms:[5]

- **Burning Plasma Science: Foundations** advances the predictive understanding of plasma confinement, dynamics, and interactions with surrounding materials—and conducts research in advanced tokamak and spherical-tokamak science, as well as small-scale magnetic confinement experiments.

- **Burning Plasma Science: Long Pulse** explores new scientific regimes using long-duration superconducting international machines, and addresses the development of materials and technologies required to withstand and sustain burning plasma.

- **Discovery Plasma Science** explores the fundamental properties and complex behavior of matter in the plasma state to improve the understanding required to control and manipulate plasmas for a broad range of applications.

- **International Thermonuclear Experimental Reactor (ITER)** is an ambitious international collaboration among seven governments (China, the European Union, India, Japan, the Republic of Korea, the Russian Federation, and the United States) to demonstrate the scientific and technological feasibility of fusion power for electricity generation. The United States contributes funding, personnel, and in-kind hardware components to the ITER facility currently under construction in France.

Key Elements of the FY 2021 Budget Proposal[6]

- **A 21 percent reduction in Basic Plasma Science: Foundations**, including a $27 million cut to research and operations at DIII-D, the largest magnetic fusion user facility in the United States; a $4 million cut to enabling R&D in high-temperature superconducting magnet technology and plasma fueling and heating technologies; and a $27.5 million cut to research and operations at the National Spherical Torus Experiment Upgrade (NSTX-U), the most powerful spherical tokamak user facility in the world. Theory and Simulation would get a boost of $7 million, most of which would go into Scientific Discovery through Advanced Computing (SciDAC) partnerships.

- **A 30 percent reduction in Basic Plasma Science: Long Pulse**, including a $6 million cut to long-pulse tokamak research, as well as a $14 million cut in the fusion nuclear science and materials research that seeks to understand how plasmas interact with the materials that might be used in future fusion facilities.

- **A 33 percent reduction in Discovery Plasma Science,** including a $5 million cut in general plasma science, which explores low-temperature plasma science and engineering; and an $8 million cut in high energy density plasma science, which explores the behavior of matter at extreme conditions of temperature, density, and pressure.

- **A 56-percent reduced contribution to the International Thermonuclear Experimental Reactor (ITER).** ITER is the only mature burning plasma experiment in the world, and the National Academies has found that no single country has the expertise or the capacity to conduct a fusion experiment at this scale.[7] As a member of ITER, the United States has committed to provide 9 percent of the construction costs in return for full access to all ITER technology and scientific data, which represents a significant opportunity for U.S. universities, laboratories, and industries to both design and construct parts, and propose and conduct experiments.[8] Reduced funding to ITER could jeopardize U.S. researchers' access to ITER technology and science.

- **A new pilot program called "Innovation Network for Fusion Energy" (INFUSE),** which aims to accelerate progress in fusion energy by establishing research partnerships with the private sector. Modeled after the successful Gateway for Accelerated Innovation in Nuclear (GAIN) Energy Voucher program, the INFUSE program provides private-sector fusion companies with access to the expertise and facilities of the Department of Energy's national laboratories.

ENDNOTES

1. DOE, "FY 2021 Congressional Budget Justification," Volume 4, DOE/CF-0165 (Washington, D.C.: DOE Chief Financial Officer, February 2020), 179–226, https://www.energy.gov/sites/prod/files/2020/02/f71/doe-fy2021-budget-volume-4.pdf.
2. The term "visible matter" includes ordinary matter made of protons, neutrons, electrons, and similar particles in the standard model of physics, but excludes dark matter and dark energy, which are inferred to exist from their effects on visible matter.
3. Ibid.
4. Fusion Energy Sciences Advisory Committee, "Applications of Fusion Energy Sciences Research" (Washington, D.C.: DOE, September 2015), https://www.osti.gov/biblio/1272148.
5. DOE, FY 2021 Congressional Budget Justification, Volume 4; see also Office of Fusion Energy Sciences, "A Ten-Year Perspective (2015–2025)" (DOE Office of Science, December 2015), https://fire.pppl.gov/FES_10Year_Perspective_2015.pdf; National Academies of Sciences, Engineering, and Medicine, "Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research" (National Academies Press, 2018), https://doi.org/10.17226/25331.
6. DOE, FY 2021 Congressional Budget Justification, Volume 4.

7. National Academies of Sciences, Engineering, and Medicine, *Interim Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research* (Washington, D.C.: The National Academies Press, 2018), 33, https://doi.org/10.17226/24971.

8. DOE, "U.S. Participation in the ITER Project," 1 (DOE, May 2016), http://www.firefusionpower.org/DOE_US_ITER_May_2016.pdf f.

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