United States Government Accountability Office

Report to the Honorable John Barrasso, M.D., U.S. Senate

January 2025

FUSION ENERGY

Additional Planning Would Strengthen DOE's Efforts to Facilitate Commercialization

GAO-25-107037

GAO Highlights

Highlights of GAO-25-107037, a report to the Honorable John Barrasso, M.D., U.S. Senate

January 2025

FUSION ENERGY

Additional Planning Would Strengthen DOE's Efforts to Facilitate Commercialization

Why GAO Did This Study

Fusion, the process that powers the sun, could produce commercial electric power to help meet growing clean energy needs if technical, economic, and other challenges are overcome. Fusion is also one of five prioritized areas to meet the U.S. goal of net-zero greenhouse gas emissions by 2050.

Congress appropriated about $760 million for FES in fiscal year 2023 to support fusion activities, including public-private partnerships.

GAO was asked to examine DOE's steps to reach the federal vision to accelerate fusion energy commercialization. This report examines (1) the status of DOE's initiatives to facilitate fusion energy commercialization, and (2) the extent to which DOE has planned for facilitating such commercialization.

GAO reviewed DOE documents; analyzed budgetary data; and interviewed federal officials and a nongeneralizable sample of eight stakeholders representing universities, industry, and interest groups. GAO selected these stakeholders based on their participation in or publication about DOE's fusion energy initiatives, and to provide a range of perspectives.

What GAO Recommends

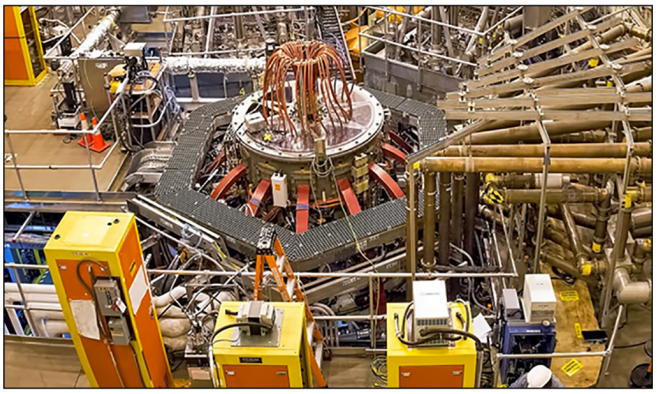
GAO recommends that the Office of Science finalize and implement ongoing fusion energy planning efforts, including by specifying roles and responsibilities, responding to identified risks, and detailing metrics and timelines for its initiatives.

View GAO-25-107037. For more information, contact Frank Rusco at (202) 512-3841 or ruscof@gao.gov.

What GAO Found

The Department of Energy (DOE), led by the Office of Science's Fusion Energy Sciences (FES) program, has taken steps to facilitate fusion energy commercialization through public-private partnerships. These efforts represented about 1.2 percent (about $36 million) of FES's total funding obligations on average during fiscal years 2020 through 2023. The rest of FES's funding obligations (about 98.8 percent on average, or about $740.8 million) went to efforts to study, among other things, the science of plasma, collaborate internationally, and maintain facilities. DOE officials indicated that the relatively limited scale of investment in initiatives to facilitate commercialization largely reflects the immature state of fusion energy technology, which GAO reported on in March 2023. Another DOE entity—Advanced Research Projects Agency-Energy (ARPA-E)—obligated nearly $50 million in fiscal year 2020, and about $8.7 million on average during fiscal years 2021 through 2023 to fusion energy commercialization projects.

A Fusion Device at the Department of Energy's Princeton Plasma Physics Laboratory



Source: Department of Energy photo. | GAO-25-107037

DOE has taken some steps to develop a vision and strategy for commercial fusion energy. For example, DOE joined an interagency working group aimed at accelerating fusion energy, among other innovations. FES created a division in April 2024 to manage strategic partnerships with private and public entities and support the transition to fusion energy demonstration and deployment activities. FES also released reports on its vision and strategy in June 2024 that identified risks to fusion energy commercialization. Although DOE has initiated planning efforts to facilitate fusion energy commercialization, whether DOE sustains these efforts is uncertain. DOE officials told GAO the interagency working group has been inactive. Working group organizers told GAO that fusion technology is in the early stages and deferred to DOE on how to facilitate commercialization. Further, DOE does not indicate with specificity or with timelines how it plans to respond to the risks identified in its June 2024 strategy. DOE's pending planning effort is expected to outline metrics and timelines. Finalizing and implementing ongoing planning efforts would better position DOE to make progress toward accelerating fusion energy commercialization and meeting the U.S. goal of net-zero greenhouse gas emissions by 2050.

Contents

Abbreviations

ARPA-E	Advanced Research Projects Agency-Energy
BETHE	Breakthroughs Enabling THermonuclear-fusion Energy
CHADWICK	Creating Hardened And Durable fusion first Wall Incorporating Centralized Knowledge
DOE	Department of Energy
FES	Fusion Energy Sciences
FIRE	Fusion Innovation Research Engine
GAMOW	Galvanizing Advances in Market-Aligned Fusion for an Overabundance of Watts
INFUSE	Innovation Network for Fusion Energy
Milestone	Milestone-Based Fusion Development Program
NNSA	National Nuclear Security Administration
NSTX-U	National Spherical Torus eXperiment-Upgrade
OSTP	Office of Science and Technology Policy
R&D	research and development

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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January 10, 2025

The Honorable John Barrasso, M.D.
United States Senate

Dear Senator Barrasso:

Fusion, the process that powers the sun, could produce commercial electric power to help meet growing clean energy needs if technical, economic, and other challenges are overcome. In 2022, the Department of Energy's (DOE) National Ignition Facility produced the first-ever fusion reaction that generated more energy than the direct energy spent to start the reaction.[1] The next steps are to close remaining science and technology gaps and resolve other challenges to prove that fusion technologies can work not only in laboratory experiments, but also in commercial power plants.

DOE's Fusion Energy Sciences program (FES), within the Office of Science, is responsible for (1) understanding matter at high temperatures and densities, (2) building the knowledge needed to develop a fusion energy source, and (3) supporting the development of a competitive fusion energy industry in the U.S. Although FES primarily leads and funds fusion energy research, development, and commercialization within DOE, the Advanced Research Projects Agency-Energy (ARPA-E) also supports these efforts.[2] ARPA-E reports directly to DOE's Secretary and Deputy Secretary and supports energy technology research and development (R&D)—including but not limited to fusion energy—that may otherwise be too high risk for private industry to undertake.

[1]Operating the lasers to run the experiment required about 100 times the energy released by the fusion event, so the experiment overall did not produce more energy than it consumed.

[2]Other DOE offices fund fusion initiatives, but they are not related to fusion energy commercialization and are therefore outside the scope of this review.

Since 2020, several governmental and nongovernmental entities have called on DOE to urgently pursue fusion energy commercialization.[3] In 2020, Congress passed the Energy Act of 2020, which mandated that DOE address challenges to building a cost competitive fusion power plant and support public-private partnerships.[4] Also in 2020, the Fusion Energy Sciences Advisory Committee—an independent body that advises DOE's Office of Science on implementation and management of FES—issued a report recommending that the department expand existing and establish new public-private partnership programs to leverage capabilities, reduce cost, and accelerate the commercialization of fusion power and plasma technologies, among other recommendations.[5]

Additionally, in 2021, the National Academies of Science, Engineering, and Medicine issued a report that discussed remaining technical challenges, made a range of recommendations, and laid out broad milestones to reach a fusion pilot plant in the 2040s.[6] Further, in 2022, White House offices, including the Office of Science and Technology Policy (OSTP), co-chaired a group that published a report assessing initial R&D opportunities to meet the administration's climate goals—net-zero greenhouse gas emissions by no later than 2050—which cited fusion

[3]DOE's Office of Technology Transfer defines commercialization as the process by which new technologies reach full commercial scale and are available in the marketplace by navigating the research, development, demonstration, and deployment continuum. DOE officials said they follow this definition of commercialization and a phased approach to commercialization with three steps: (1) addressing gaps in physics and technology, (2) building infrastructure to demonstrate fusion technologies at scale, and (3) supporting development of fusion pilot plant designs.

[4]Consolidated Appropriations Act, 2021, Pub. L. No. 116-260, div. Z, tit. II, § 2008(a), 134 Stat. 1182, 2474–78 (2020) (codified as amended at 42 U.S.C. § 18645). The Energy Act of 2020 is div. Z of the Consolidated Appropriations Act, 2021. The Energy Act of 2020 also mandated DOE carry out research activities to expand the fundamental understandings of plasma and matter at very high temperatures and densities for fusion applications and for other engineering and plasma science applications. Public-private partnerships are arrangements in which public and private resources—such as DOE, fusion companies, and universities—are combined to achieve a mutually beneficial goal—such as commercialization of fusion energy.

[5]Fusion Energy Sciences Advisory Committee, *Powering the Future: Fusion & Plasmas* (Washington, D.C.: 2020).

[6]National Academies of Sciences, Engineering, and Medicine, *Bringing Fusion to the U.S. Grid* (Washington, D.C.: 2021).

energy at scale as one of five prioritized areas.[7] Congress appropriated about $760 million for FES in fiscal year 2023 to support fusion activities.

Several challenges must be overcome to achieve commercial fusion energy, as we discussed in a 2023 technology assessment.[8] Beyond technical challenges, we found that public and private sector misalignments in research priorities presented challenges to fusion energy development. We presented policy options to help address this misalignment challenge and others, including that policymakers align programs, missions, and organizational structures with fusion energy development goals; expand the use of public-private partnerships; and reduce barriers to collaboration.

You asked us to examine the extent to which DOE is taking steps to achieve the federal vision to accelerate fusion energy commercialization.[9] This report examines (1) the status of DOE's initiatives to facilitate fusion energy commercialization, and (2) the extent to which DOE has planned for facilitating such commercialization.

To determine the status of DOE's initiatives to facilitate fusion energy commercialization, we reviewed DOE documentation describing ongoing and planned fusion energy initiatives. We also analyzed data on appropriated and obligated funding for fusion energy during fiscal years 2020 through 2023, the latest year available at the time of our review. The scope of our review focused on U.S. initiatives directly related to DOE

[7]Net-Zero Game Changers Interagency Working Group, National Climate Task Force, *U.S. Innovation to Meet 2050 Climate Goals: Assessing Initial R&D Opportunities* (Washington, D.C.: The White House, November 2022). The report identified fusion energy as a high-risk, high-reward technology and specified that making fusion energy cost-competitive with conventional energy is key to helping the U.S. reach climate goals.

[8]GAO, *Technology Assessment, Fusion Energy: Potentially Transformative Technology Still Faces Fundamental Challenges*, GAO-23-105813 (Washington, D.C.: Mar. 30, 2023).

[9]We initiated this work at the request of the former Chairman and Ranking Member of the Senate Committee on Energy and Natural Resources.

fusion energy commercialization efforts.[10] We assessed the reliability of the data by interviewing DOE officials about their data management practices and reviewing relevant documentation. We determined that the data were sufficiently reliable for describing past appropriated and obligated funding for fusion energy.

To evaluate the extent to which DOE has planned for facilitating fusion energy commercialization, we reviewed DOE's plans to implement its fusion energy initiatives. We also reviewed documentation on DOE's internal and external communication efforts in implementing those fusion energy initiatives. In addition, we reviewed DOE's policy that establishes expectations for program management.[11] We then assessed DOE's plans and the extent to which they fulfilled the expectations outlined in DOE's policy.

To address both objectives, we interviewed DOE officials and visited a DOE national laboratory and user facility involved in fusion energy R&D.[12] We interviewed officials from OSTP and a nongeneralizable sample of eight U.S. stakeholders to identify the status of DOE's fusion energy initiatives and the extent to which DOE has planned for facilitating the commercialization of fusion energy. We selected these stakeholders—universities, industry, and interest groups—based on their participation in or publication about DOE's fusion energy initiatives. They represent a

[10]We focused our review on FES and ARPA-E because fusion energy initiatives of other DOE offices are not related to commercialization. For example, the National Nuclear Security Administration (NNSA)—a separately organized agency within DOE—manages efforts to modernize the nuclear stockpile and related infrastructure, among other functions. According to NNSA officials, the agency is not engaged in commercial fusion energy initiatives. However, NNSA-managed national laboratories conduct fusion experiments with fusion companies on an ad hoc basis, and its capabilities and expertise could be leveraged to advance fuel supply chains and nonproliferation frameworks needed for global commercial fusion energy deployment. Likewise, the Office of Nuclear Energy—within the Office of the Under Secretary for Science and Innovation—advances nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. According to an official from the Office of Nuclear Energy, the office is not engaged in fusion energy initiatives.

[11]*See* Department of Energy, *Program Management*, Policy 410.3 (Washington, D.C.: Sept. 23, 2021). This policy establishes DOE's expectations for program management in response to the Program Management Improvement Accountability Act of 2016, Pub. L. No. 114-264, 130 Stat. 1371, among others.

[12]We visited the Princeton Plasma Physics Laboratory, which is a DOE national laboratory managed by Princeton University. We also visited the FES user facility, the National Spherical Torus eXperiment-Upgrade (NSTX-U), which is located at the laboratory.

range of perspectives among those producing and working with different fusion energy technologies.

We conducted this performance audit from August 2023 to January 2025 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Fusion Energy and Technologies

Fusion is a potential energy source and occurs when one or more lighter elements combine to form a heavier element, releasing energy in the process. By comparison, current nuclear reactors use fission, where heavier elements split into lighter elements. Fusion requires extreme heat and either high pressure or confinement in a small space, which is challenging to achieve on Earth. Fusion experiments often use temperatures greater than 180 million degrees Fahrenheit. The high temperature needed for fusion creates plasma, which is difficult to control, and which researchers are still working to fully understand. Plasma is often called the fourth state of matter, along with solid, liquid, and gas.[13]

There are two commonly pursued pathways to try to create and control plasma:

- **Magnetic confinement** uses strong magnets to contain plasma. One common magnetic confinement device is a tokamak, which contains plasma using a donut shape.
- **Inertial confinement** uses high-power lasers or electrical discharges to compress a small capsule of fusion fuel to extreme temperatures and pressures for a short time.

Beyond the two commonly pursued pathways, U.S. companies are pursuing various other pathways to try to create and control fusion reactions, including a hybrid of both magnetic and inertial confinement approaches.

[13]Plasma is a state of matter where some of the electrons are separated from the neutral atoms. Plasma comprises over 99 percent of the visible universe, including stars and lightning.

Various fusion fuels are used to power these pursued pathways. Deuterium-tritium is a highly studied fusion fuel and a likely basis for the first fusion power plants.[14] While deuterium is a relatively abundant material, the global supply of tritium is too limited to meet the needs of potential commercial fusion power plants and poses other issues like health risks and nuclear weapon proliferation concerns. Some researchers have proposed a breeding blanket—a theoretical component of a fusion device that would create tritium and reduce supply constraints. Developing a breeding blanket is just one of many technical challenges researchers must overcome to progress fusion energy technology toward a fusion pilot plant.

Regardless of the pathway and fusion fuel, a future fusion plant could use the heat produced by the fusion reaction to produce steam to drive turbines or generators that produce electricity, just like conventional power plants. Fusion plants may use deuterium-tritium fuel that could result in low-level radioactive waste.

History of Fusion Funding and Research in the U.S.

The U.S. has been federally funding fusion research since 1951, though the overarching mission of the U.S. fusion program has varied over the years.

At inception, the U.S. fusion program aimed to investigate the feasibility of generating electricity through fusion reactions via magnetic confinement research. In 1963, a DOE predecessor agency began funding laser fusion research. However, amid funding reductions, Congress directed the program in fiscal year 1996 to refocus on basic plasma science and technology foundations, including through international collaboration.[15] According to a 1996 DOE report that recommended the restructure, focusing on basic plasma science and technology foundations would be

[14]Deuterium and tritium are different versions of hydrogen. Deuterium-tritium fusion reactions are easier to achieve than fusion reactions using other fusion fuels, as deuterium-tritium requires a lower temperature. For a fusion energy system to be viable, it must produce more energy through fusion reactions than the overall energy needed to produce and maintain those reactions in a plasma. Viable fusion energy systems will need to integrate into power plants and incorporate fusion reactors as well as supporting structures, systems, and components.

[15]*See* H. Rept. 104-293 (conference report to accompany "Energy and Water Development Appropriations Act, 1996," H. R. 1905, 104th Cong.).

less costly than developing a fusion power plant and would be in line with budget realities at the time.[16]

DOE has long provided significant funding to fusion energy commercialization efforts through an international experimental fusion reactor project called ITER.[17] ITER, the design of which began in 1988, is intended to bridge the gap between today's smaller-scale experimental fusion devices and the demonstration fusion power plants of the future, according to ITER's website. Thirty-three participating countries, including the U.S., have agreed to share the cost of construction, operation, and decommissioning of ITER, as well as intellectual property. The project is ongoing, and the participating countries will need to address many of the technical challenges of commercial fusion energy after construction is completed. During fiscal years 2013 through 2023, ITER received about 30 percent of FES's appropriations, averaging about $163 million annually.[18] Since the project began, ITER has experienced decades of delays and is now estimated to begin operations in 2034 (see fig. 1).[19]

[16]Fusion Energy Advisory Committee, *A Restructured Fusion Energy Sciences Program*, (Washington, D.C.: Jan. 27, 1996).

[17]ITER originally stood for the International Thermonuclear Experimental Reactor, but the name is no longer used for the project. Instead, the project is simply referred to as ITER. Because this review focuses on DOE's efforts to facilitate U.S. fusion energy commercialization, examining the U.S.'s contributions to ITER is outside the scope of this review.

[18]ITER received a one-time additional obligation of about $250 million in fiscal year 2022 from the appropriations to the Office of Science in the Inflation Reduction Act, according to data provided by FES.

[19]We have previously reported on delays and cost overruns associated with ITER. See GAO, *Fusion Energy: Actions Needed to Finalize Cost and Schedule Estimates for U.S. Contributions to an International Experimental Reactor*, GAO-14-499 (Washington, D.C.: June 5, 2014). Specifically, we found that DOE had been unable to finalize its cost and schedule estimates in part because the international project schedule to which the estimates were linked was not reliable. We also found that DOE had taken several actions that have reduced U.S. ITER costs, but that DOE had not adequately planned for the potential impact of those costs on the overall U.S. fusion program. We made four recommendations to reduce uncertainty about the expected cost and schedule of the U.S. ITER Project and its potential impact on the U.S. fusion program. All four were subsequently closed as implemented.

Figure 1: View of ITER Site, as of June 2024

Source: ITER Organization. | GAO-25-107037

Congress redirected the program's mission again in the Energy Act of 2020. Specifically, the act mandated that the program work toward facilitating fusion energy commercialization by addressing challenges to building a cost competitive fusion power plant and supporting the development of a competitive fusion energy industry in the U.S. through public-private partnerships.[20]

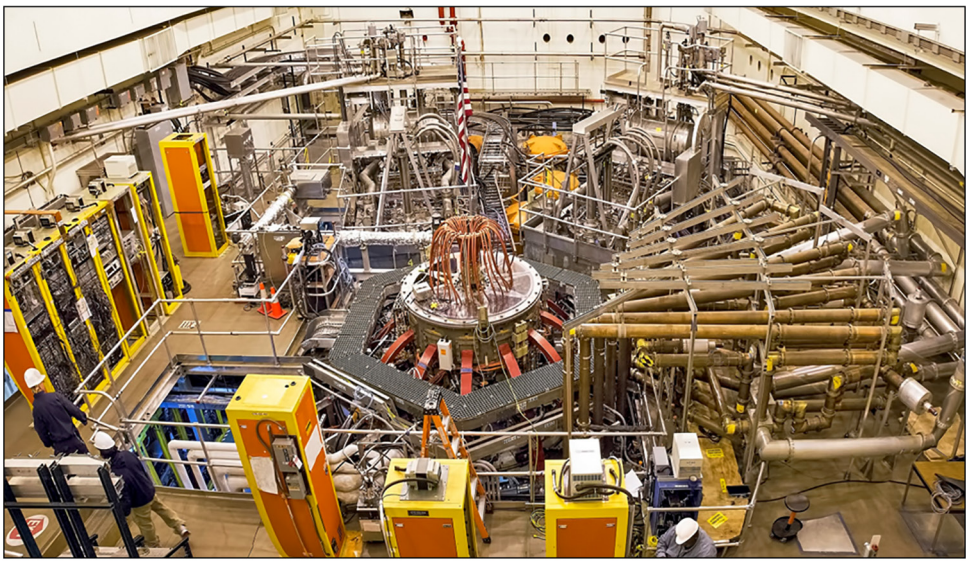
Fusion R&D has been carried out at national laboratories and user facilities managed by private companies or universities.[21] For example, Princeton Plasma Physics Laboratory and Oak Ridge National Laboratory have been conducting fusion R&D since the 1950s, and they participate in initiatives to facilitate fusion energy commercialization. DOE has two user facilities that conduct R&D on fusion energy. The DIII-D National Fusion Facility began operating in 1986 and continues to operate. The National Spherical Torus eXperiment-Upgrade (NSTX-U) operated from

[20]Pub. L. No. 116-260, § 2008(a), 134 Stat. at 2474–78 (codified as amended at 42 U.S.C. § 18645).

[21]A user facility is a federally sponsored research facility available for external use to advance scientific or technical knowledge.

1999 to 2010 and then briefly in 2016 (see fig. 2).[22] NSTX-U has been undergoing repairs and upgrades since 2016 and is expected to operate again once repairs and upgrades are completed.

Figure 2: A Fusion Device, the National Spherical Torus eXperiment-Upgrade, at Princeton Plasma Physics Laboratory



Source: Department of Energy. | GAO-25-107037

Notes: A spherical torus is an alternative magnetic confinement device that is shaped more like a cored apple than the donut-like shape of a conventional tokamak. The National Spherical Torus eXperiment-Upgrade has been under repair and upgrades since 2016. The photo was taken in fiscal year 2024.

Federal funding for fusion remained generally consistent during fiscal years 2012 through 2022, according to data provided by DOE. In fiscal

[22]The National Spherical Torus eXperiment located at the Princeton Plasma Physics Laboratory first began operating in 1999. It underwent an upgrade from 2010 to 2016. In 2016, the device was renamed to the National Spherical Torus eXperiment-Upgrade (NSTX-U). NSTX-U briefly operated in 2016 until a coil failed.

year 2022, federal funding peaked at about $990 million, including supplemental Inflation Reduction Act support.[23]

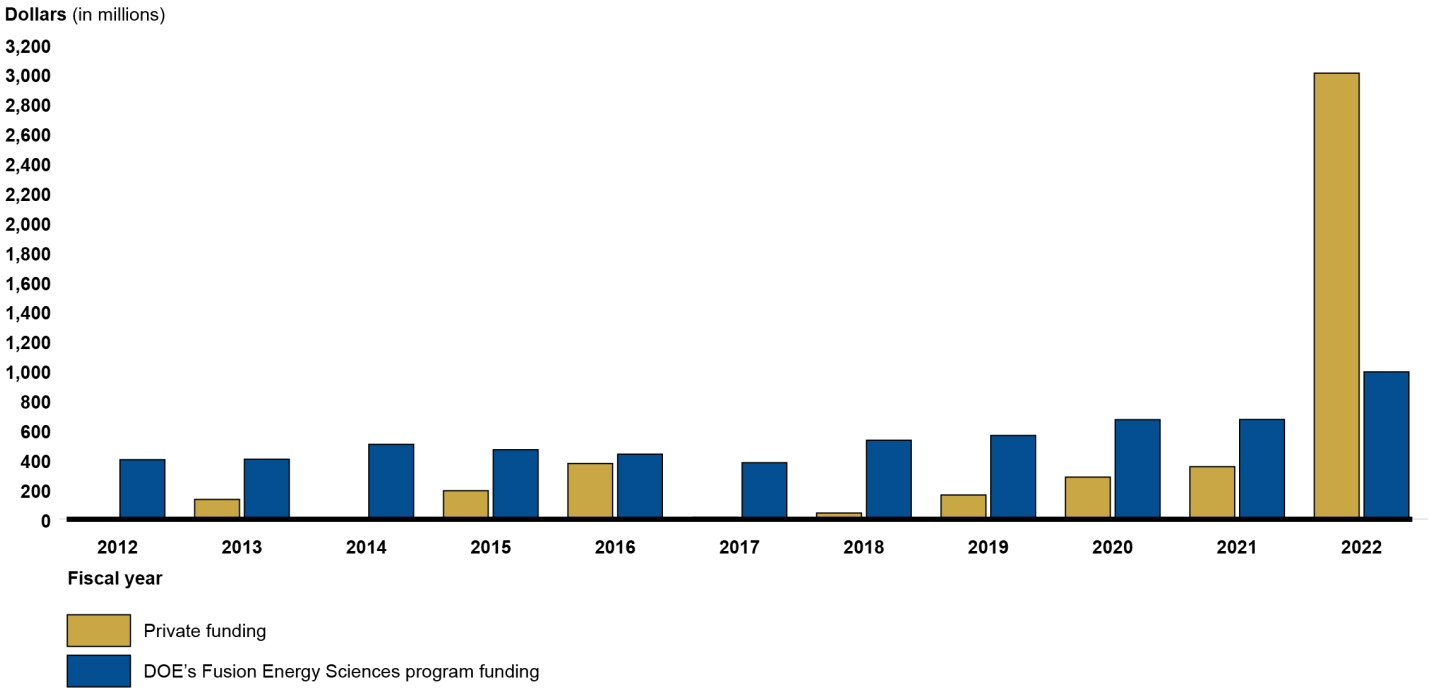
The private sector funds fusion R&D, and privately financed fusion R&D has experienced rapid growth that has spurred an emerging fusion energy industry, according to independent reports.[24] Private funding generally remained under $300 million annually during fiscal years 2012 through 2020, according to data provided by DOE. The private sector provided a large increase in fiscal year 2022 to over $3 billion, with 60 percent of this amount going to one U.S. fusion energy company. The fusion industry has attracted a total of approximately $7.1 billion in private investments, as of calendar year 2024, according to a 2024 report by an industry association (see fig. 3).[25] Of the 45 known fusion companies in the world, 25 have primary headquarters in the U.S., according to the report. About half (27) of these companies were founded after calendar year 2019. According to the responses of 35 companies to a survey conducted by the industry association, most companies (22) anticipate delivering power to the grid between calendar years 2030 and 2035.

[23]FES received supplemental funding from the Inflation Reduction Act of about $280 million in fiscal year 2022, according to data provided by FES. "An Act To provide for reconciliation pursuant to Title II of S. Con. Res. 14," Pub. L. 117-169, tit. V, § 50172(a)(3), 136 Stat. 1818, 2050 (2022) (commonly known as the "Inflation Reduction Act").

[24]Fusion Energy Sciences Advisory Committee, *Powering the Future: Fusion & Plasmas*; and National Academies of Sciences, Engineering, and Medicine, *Bringing Fusion to the U.S. Grid*.

[25]Fusion Industry Association, *The Global Fusion Industry in 2024: Fusion Companies Survey by the Fusion Industry Association* (Washington, D.C.: 2024). The Fusion Industry Association is a non-profit organization with a membership of private companies working to make commercial fusion energy a reality.

Figure 3: Fusion Energy Funding, Fiscal Years 2012–2022



Source: GAO analysis of information from the Department of Energy (DOE). | GAO-25-107037

Notes: Private funding includes both U.S. and international funding amounts. The figure may underrepresent private funding because not all private funding is publicly announced. Private funding for fiscal years 2014 and 2017 ranged from about $4 million to $12 million (not visible in the figure). Private sector funding experienced a large increase in fiscal year 2022 to over $3 billion, with nearly two-thirds of this amount going to one U.S. fusion energy company.

DOE's Fusion Energy Science program is the main federal entity tasked with pursuing fusion energy research, development, and commercialization. Appropriated funding amounts are from public budget request documents.

Beyond the federal government and private industry, universities also contribute to fusion R&D. DOE's website lists over 60 U.S. universities with fusion or plasma physics programs. Many of these universities participate in federal fusion initiatives. Universities received about 20 percent of FES's research budget in fiscal year 2022, according to a university association white paper.[26] For example, universities experiment to develop approaches to generating fusion energy in stellarators, which are magnetic confinement devices that serve as an alternative to

[26]The University Fusion Association is a non-profit organization composed of professional and student researchers in educational institutions throughout the U.S. The budget number does not include U.S. contributions to ITER.

tokamaks. In addition, universities are the main source of the workforce needed to further fusion R&D and execute the federal vision to commercialize fusion energy, according to the same university association.

DOE Has Made Initial Investments in Fusion Energy Commercialization Initiatives and Proposed More

DOE's Initial Investments in Commercialization Initiatives

DOE, led by FES, has recently taken steps to facilitate fusion energy commercialization through initiatives that support public-private partnerships. According to DOE data, DOE obligations funded four initiatives during fiscal years 2020 through 2023 that were specific to directly facilitating commercialization through FES and ARPA-E.[27] DOE officials said these initiatives were complementary as they fund projects at different levels of technology maturity, and some awardees have participated in multiple initiatives, according to DOE data. Across these years, FES obligated a total of about $36 million to directly facilitating fusion energy commercialization. ARPA-E obligated a total of about $75 million to fusion energy research, development, and commercialization. These efforts represented a small percentage of DOE's total fusion energy funding obligations (about 3.6 percent)—and an even smaller percentage of FES's total funding obligations (about 1.2 percent)—on average during these years.

DOE officials indicated that the relatively limited scale of investment in initiatives to facilitate commercialization to date largely reflects the immature state of fusion energy technology. Because fusion energy development is in relatively early stages, DOE officials said that FES must balance support of commercialization with support of scientific

[27]Budget authority is the amount of money for which DOE has legal authority—generally through appropriations—to enter into financial obligations that will result in immediate or future outlays of federal government funds. Once Congress provides the budget authority to DOE, the agency can incur an obligation—a definite commitment that creates a legal liability of the government for the payment of goods and services ordered or received, or a legal duty on the part of the U.S. that could mature into a legal liability by virtue of actions on the part of the other party beyond the control of the U.S.

research, such as basic plasma science, to address scientific and technical gaps. Officials told us that other initiatives addressing basic science and technology challenges are critical to facilitating eventual fusion energy commercialization, and officials have built connections with the private sector in ways that are not captured in commercialization funding.

Although the U.S. has been federally funding fusion research since 1951, key technologies needed to achieve fusion energy commercialization remain at low technology readiness levels.[28] For example, DOE officials told us that FES would like to focus on known technology gaps, such as tritium breeding blankets.[29] The Fusion Energy Sciences Advisory Committee reported in 2020 that breeding-blanket and tritium-handling systems were not yet advanced enough for a fusion pilot plant and recommended that FES rapidly expand the R&D effort in fusion materials and technology. However, there has been no large-scale demonstration of a tritium breeding blanket, which is likely needed to fuel the first fusion power plants.

[28]DOE defines technology readiness levels as a metric used to assess maturity of evolving technologies.

[29]A 2023 report by an industry association stated that the availability of future supply constraints for fuels such as tritium was a top concern among private fusion companies. Fusion Industry Association, *The Fusion Industry Supply Chain: Opportunities and Challenges* (Washington, D.C.: 2023).

FES

Fusion Energy Sciences' (FES) User Facilities

User facilities are federally sponsored research facilities available for external use to advance scientific or technical knowledge. Two user facilities with tokamaks—devices that confine plasma using magnetic fields—receive FES funding. The facilities do not participate in DOE's initiatives to facilitate commercialization through U.S. public-private partnerships, but international stakeholders use one of the facilities to conduct experiments, according to DOE officials and documentation.

DIII-D National Fusion Facility (DIII-D). Pictured below, DIII-D in California aims to optimize the tokamak for fusion energy production. DIII-D has over 50 diagnostic systems to monitor experiments. In fiscal year 2022, it had 666 users, including from the fusion industry. For example, three companies developed machine learning tools for plasma control at DIII-D.

National Spherical Torus eXperiment-Upgrade (NSTX-U). NSTX-U in New Jersey aims to explore the advantages of a compact tokamak. NSTX-U has been undergoing repairs and upgrades since 2016, and officials expect it to be operational in fiscal year 2027. NSTX-U officials said they have not discussed involving the facility in DOE's initiatives to facilitate commercialization through U.S. public-private partnerships. However, they expect users, including fusion industry and international stakeholders, could run data and diagnostic experiments at NSTX-U.

Sources: Department of Energy (DOE) data and documents; General Atomics (photo). | GAO-25-107037

FES is managing two ongoing initiatives intended to facilitate fusion energy commercialization through public-private partnerships: the Milestone-Based Fusion Development Program (Milestone) and the Innovation Network for Fusion Energy (INFUSE). These two initiatives represented a small percentage (about 0.7 percent, or about $5.4 million) of FES's total average annual fusion energy obligations (about $750 million) from fiscal years 2020 to 2023.

FES obligated the remaining 98.8 percent of average annual fusion energy funds (about $740.8 million) to initiatives studying the science of plasma,[30] international collaboration, existing and new user facilities, fusion theory and simulation, and artificial intelligence and machine

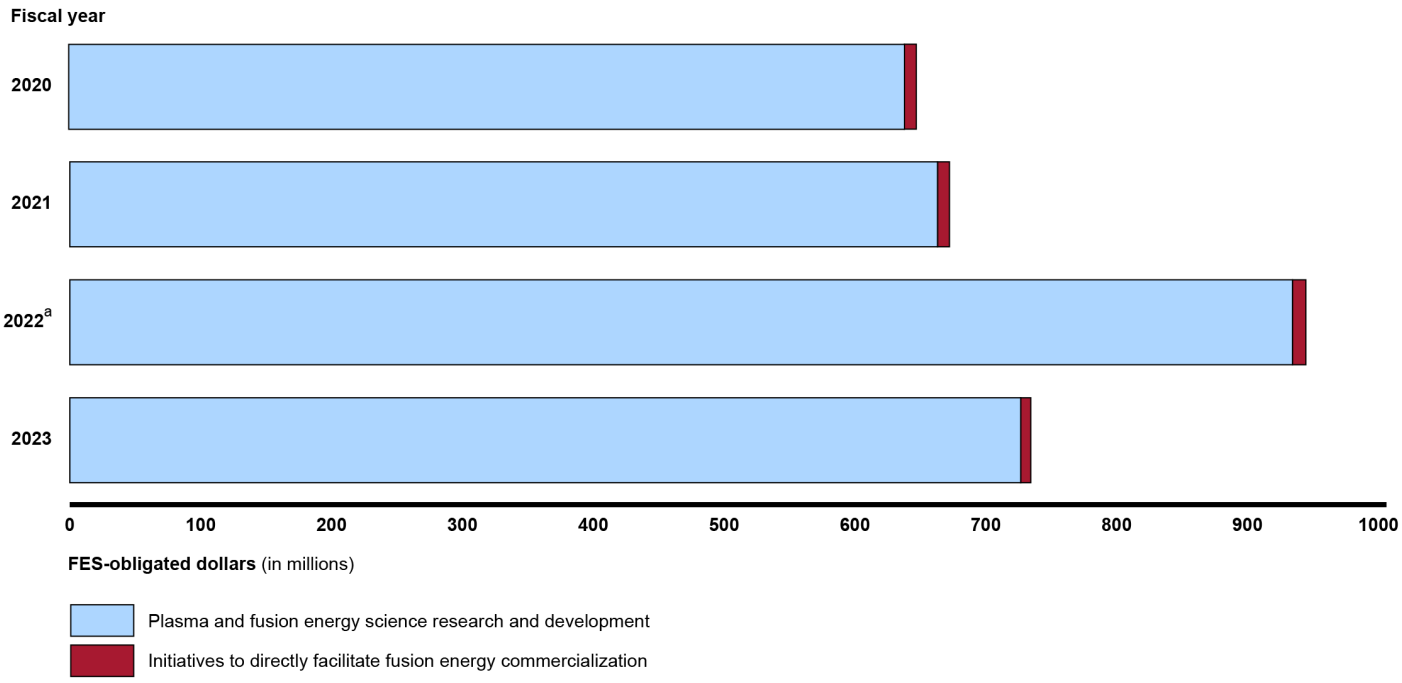
[30]As we previously reported in 2023, researchers do not fully understand the behavior of burning plasma, making it difficult to optimize plasma confinement and reliably drive fusion energy production. GAO-23-105813.

learning, among other things (see fig. 4).[31] DOE officials noted that some of its other spending contributes to addressing basic science and technology challenges that must be overcome to progress toward a fusion pilot plant.[32] Among these initiatives, and as previously discussed, ITER—the international fusion energy commercialization experiment—has long accounted for a significant portion of FES's total annual appropriations ($163 million, or about 30 percent, during fiscal years 2013 through 2023). Recent increases in private sector fusion investment as well as FES's appropriations have not affected DOE's commitment to ITER—DOE's most recent budget submission indicates continued support at existing funding levels, which far surpass what it has obligated in its more recent domestic commercialization efforts described below.

[31]Nearly 70 percent of FES's obligations (about $519 million on average) supports three sites, including two DOE user facilities located in the U.S. The two DOE user facilities supported by FES funding are DIII-D National Fusion Facility and NSTX-U. The third site is ITER.

[32]According to DOE officials, about half of FES's research funding during fiscal years 2020 through 2024 supported activities that could ultimately support commercialization. Officials told us they interpret "commercialization" broadly and that this estimate excluded funding for non-research activities, among other line items. In contrast, we analyzed obligations during fiscal years 2020 through 2023 for FES's public-private partnerships and initiatives that directly related to facilitating fusion energy commercialization, as a proportion of FES's total obligations.

Figure 4: FES Funding Obligations for Fusion Energy Research, Development, and Initiatives to Directly Facilitate Commercialization, Fiscal Years 2020–2023



Source: GAO analysis of Department of Energy's Fusion Energy Sciences (FES) program data. | GAO-25-107037

[a]Includes additional obligated funding from the Inflation Reduction Act of 2022.

Milestone. In September 2022, FES announced the Milestone initiative, which aims to advance designs and R&D for fusion pilot plants.[33] The Milestone initiative required each applicant to propose a series of milestones toward designing a fusion pilot plant, and DOE funding is contingent upon meeting those milestones. Each selected company would deliver a preconceptual design and a technology roadmap for a fusion pilot plant to DOE, likely in late 2025 or early 2026.[34] A DOE official said the Milestone initiative will fulfill a key component of the National Academies' recommendations for commercializing fusion energy—

[33]This initiative is required by 42 U.S.C. § 18645.

[34]According to DOE's funding opportunity announcement, the preconceptual design addresses the same issues as the conceptual design but at lower levels of fidelity and with greater uncertainties. A technology roadmap identifies in detail the required critical-path R&D, including any intermediate test facilities, and focuses on the advances required for a particular fusion pilot plant conceptual design.

specifically, to develop conceptual pilot plant designs and technology roadmaps and lead to a preliminary engineering design of a fusion pilot plant. Officials described the Milestone initiative as the primary initiative for facilitating fusion energy commercialization and the central mechanism for partnering with the private sector to work toward the preliminary design of a fusion pilot plant.

In May 2023, FES announced the selection of eight companies to receive a total of $46 million in funding, with individual companies selected to receive between $3 million and $15 million over the first 18 months of the initiative. These companies are expected to contribute more than 50 percent of total costs from non-federal sources. Overall, Congress appropriated just over $86 million for the initiative as of fiscal year 2024, while DOE obligated about $46 million with the conclusion of negotiations with awardees.[35]

Although the selection was announced in May 2023, negotiations to finalize funding agreements lasted until June 2024 in large part due to company concerns regarding intellectual property provisions, according to DOE officials and stakeholders. Specifically, two industry stakeholders told us that they did not apply to the initiative because, as is standard, the government could retain an interest in any resulting intellectual property. One of these industry stakeholders told us that it did not think it would financially gain from being awarded the Milestone initiative, while the other told us that the Milestone award amounts are small relative to amounts of private capital it had raised. DOE officials told us that, although the awards were relatively small, DOE's vetting and approval process lent credibility to and spurred increased investor confidence in the selected companies.

FES was required in statute to use other transaction authorities—which include the flexibility to modify standard government terms and conditions, including intellectual property rights provisions—in lieu of standard cooperative agreements.[36] Officials told us that the parties agreed in negotiations that government rights would not attach to

[35]Congress authorized $415 million for fiscal years 2021 through 2027 for the Milestone initiative, even though only $46.35 million was appropriated during fiscal years 2022 and 2023. DOE obligated $350,000 in fiscal year 2023 and $46 million in fiscal year 2024.

[36]42 U.S.C. § 18645(i). The referenced authorities are in 42 U.S.C. § 7256(g).

inventions until after a company achieved a milestone that would result in a federal payment.

INFUSE. FES began the INFUSE initiative in 2019 to provide fusion companies with access to technical expertise and resources—rather than direct funding—at DOE laboratories to conduct R&D of new or existing fusion technologies. In 2022, FES expanded the initiative to allow universities, in addition to DOE laboratories, to provide technical expertise and resources to fusion companies. To participate in INFUSE, fusion companies propose projects in one of six general topics, such as materials science. DOE officials said they added "paths to commercialization" as a topic in 2023.

According to obligations data provided by FES, INFUSE supported 91 projects with about $19.5 million of in-kind support during fiscal years 2020 through 2023. For each project, INFUSE typically awards between $100,000 and $350,000 for a 12-month duration, but projects can receive up to $750,000 and last for up to 24 months, according to DOE documentation.[37] Fusion companies are required to contribute at least 20 percent of the full project cost. For example, one project aimed to create a low-cost manufacturing process for components of fusion devices that can support design changes and the use of new materials. The national laboratory received $400,000 from the INFUSE program to pursue research of interest to a private company, according to obligations data provided by FES. This project could make design changes easier during the development of early fusion devices and lengthen the lifespan of potential future commercial devices by enabling replacement of components, according to the project's final report.

ARPA-E

ARPA-E is also managing two ongoing initiatives to support fusion energy research, development, and commercialization: Breakthroughs Enabling THermonuclear-fusion Energy (BETHE) and Galvanizing Advances in Market-Aligned Fusion for an Overabundance of Watts (GAMOW). ARPA-E has also made awards related to facilitating fusion energy research, development, and commercialization through broader funding opportunities for exploratory research. However, fusion energy is a small component of ARPA-E's mission, according to an ARPA-E official. ARPA-E obligated nearly $50 million in fiscal year 2020, and then about $8.7

[37]Awards are not financial awards made directly to applicants. Awards provide funding to a laboratory or university to help eligible private-sector companies overcome scientific or technological challenges.

million on average during fiscal years 2021 through 2023 to fusion energy projects that facilitate commercialization across various initiatives.[38]

BETHE. The BETHE initiative aims to deliver lower-cost fusion energy options by advancing the performance of inherently lower cost but less mature fusion energy concepts, among other research categories. ARPA-E announced awards for this initiative in fiscal year 2020. It made 18 awards and obligated a total of nearly $44 million during fiscal years 2020 through 2023, according to obligations data provided by ARPA-E. For example, two universities received about $5 million and $10 million to explore the concept of using mirrors to create and control plasma, according to obligations data provided by ARPA-E.

GAMOW. GAMOW is a joint initiative between ARPA-E and FES that aims to develop technologies and materials needed to sustain commercially attractive fusion energy. DOE announced awards for this initiative in fiscal year 2020. ARPA-E and FES each contributed about $15 million for a total of about $30 million, according to obligations data provided by ARPA-E and FES.[39] The initiative made 14 project awards during fiscal years 2020 through 2023. For example, one university received almost $700,000 to research how to decrease erosion of electrodes—conductors used to electrically confine and accelerate ions to cause fusion reactions—which could decrease maintenance costs of future fusion power plants.[40]

[38]According to an ARPA-E official, ARPA-E fusion energy initiatives apply and compete against other ARPA-E initiatives for a portion of the total dollars appropriated by Congress to ARPA-E. Once an APRA-E initiative is approved, it is fully funded and obligated. Across all initiatives, ARPA-E obligated about $400 million on average annually during fiscal years 2020 through 2023.

[39]Although both ARPA-E and FES provided obligated funding to GAMOW from fiscal years 2020 through 2024, ARPA-E leads the initiative.

[40]Although FES and ARPA-E initiatives are separate and distinct, there is crossover of awardees, according to DOE officials. For example, some of the high-risk projects funded by ARPA-E matured technology enough to then be selected for FES's INFUSE initiative. Five out of the eight companies selected for the Milestone initiative had previously been selected to participate in ARPA-E initiatives. Likewise, six of the eight companies selected for the Milestone initiative had previously been selected to participate in the INFUSE initiative.

DOE's Proposed Additional Commercialization Initiatives

DOE, through both FES and ARPA-E, has proposed new initiatives to facilitate fusion energy commercialization. However, the FES-led initiatives are in early stages of implementation or conceptualization. Some examples of initiatives include the following:

FIRE Collaboratives. In May 2023, FES announced its Fusion Innovation Research Engine (FIRE) Collaboratives initiative, which will aim to advance foundational science towards practical application by addressing materials and technology gaps, such as breeding blankets. FES envisions FIRE Collaboratives will eventually address the materials and technology gaps identified by companies selected for the Milestone initiative, according to the funding opportunity announcement. FES expects FIRE Collaboratives to be a collection of centrally managed teams that include public and private partners, such as universities, private companies, and national laboratories. In a public presentation, DOE announced funding of up to $180 million for the initiative, with an estimated $2 million to $5 million going to each awardee per year for 4 years. The exact funding amount and number of awards will depend on the applications received and availability of funding, according to a FES document. FES requested $60 million for fiscal year 2025 to support FIRE Collaboratives.

CHADWICK. In January 2024, ARPA-E announced the Creating Hardened And Durable fusion first Wall Incorporating Centralized Knowledge (CHADWICK) initiative, which aims to develop materials for the chamber of a fusion device in which the fusion reaction takes place. The chamber will face an extreme environment, such as high heat, and the material it is made of must be able to maintain safety and structural performance over the lifetime of a fusion power plant. ARPA-E announced 13 project award selections in September 2024 totaling just under $30 million. For example, one project will develop an open-source library to assess and document the radioactivity of materials that could be used in fusion power plants.

Fusion Energy Public-Private Consortium Framework. In June 2024, FES requested stakeholder feedback on a potential Fusion Energy Public-Private Consortium Framework. If formalized, this potential initiative would aim to advance fusion energy research, development, demonstration, and deployment by delivering and operating small-to-medium scale testing facilities and conducting R&D.[41] This potential

[41]Officials told us that they expect the initiative to focus on R&D to address science and technology gaps.

initiative is in the early stages of conceptualization and is currently unfunded.

DOE Has Not Completed Plans to Guide Future Investments in Fusion Energy Commercialization

DOE recognizes the need to facilitate the development of commercial fusion energy, which is consistent with the Energy Act of 2020's requirement for DOE to address challenges to building a cost-competitive fusion power plant and support a competitive U.S. fusion power industry. In March 2022, OSTP and DOE announced that they would develop a bold decadal vision for commercial fusion energy and described initial steps the federal government would take to develop a comprehensive decadal vision and strategy. In March 2022, OSTP and DOE hosted a summit to launch a DOE-wide initiative to accelerate the viability of commercial fusion energy in partnership with the private sector and discuss remaining challenges. Since the March 2022 announcement and summit, DOE has taken the following steps to plan for facilitating fusion energy commercialization:

Fusion crosscut team. In September 2022, DOE formed a department-wide initiative called the fusion crosscut team that aims to leverage the capabilities of DOE's program offices to facilitate fusion energy commercialization. According to DOE officials, the crosscut team's role is to connect programs within DOE and reduce barriers to collaboration. Officials told us that the crosscut team meets monthly to share updates on programs across the agency and to discuss planning and priorities. Officials told us that there were no slide decks or meeting notes because the meetings are informal.

Net-Zero Game Changers Initiative. DOE officials told us that the agency joined the Net-Zero Game Changers Initiative in 2022 to support development of the bold decadal vision. The Net-Zero Game Changers Initiative was an interagency working group formed by the White House Climate Policy Office, OSTP, and the Office of Management and Budget to identify, prioritize, and accelerate climate innovations. The initiative cites fusion energy, at scale and cost-competitive with conventional energy, as one of five priorities to help reach U.S. goals of net-zero emissions by 2050.

FES reorganization. In April 2024, FES announced a reorganization and created a new third division, Enabling Science and Partnerships.[42] According to a March 2024 memo, the new division is intended to address the expanded FES mission established in the Energy Act of 2020. The division will oversee all fusion energy public-private partnerships and support the future transition to demonstration and deployment activities. According to DOE officials, the new division will address strategic partnerships with various actors, such as state and local governments, other DOE offices, national laboratories, and international partners. Officials also told us that the new division would help ensure that FES's initiatives and projects track with the needs of the private sector and address critical gaps in research, development, and technology.

FES vision. In June 2024, the Office of Science released a report outlining its vision for the future of the FES program.[43] The report noted that the Energy Act of 2020 updated FES's mission from expanding the fundamental understanding of matter at very high temperatures and densities and building the scientific foundations needed to develop a fusion energy source, to also supporting the development of a competitive fusion power industry in the U.S. The report highlighted three strategic areas FES would focus on to meet this mission: (1) building a U.S. fusion science and technology roadmap, (2) establishing FIRE Collaboratives, and (3) developing a public-private consortium framework focused on delivering and operating fusion technology facilities and conducting R&D to close science and technology gaps.

Decadal fusion energy strategy. Also in June 2024, DOE published a decadal fusion energy strategy, which organized DOE's fusion energy goals into three high-level objectives: (1) closing science and technology gaps to a commercially relevant fusion pilot plant; (2) preparing the path to sustainable, equitable commercial fusion energy deployment; and (3)

[42]Prior to the FES reorganization, FES comprised the Research Division and the Facilities and Projects Division. FES added the Enabling Science and Partnerships Division and changed the areas under the two existing divisions. For example, FES merged several research areas under a single newly named Tokamak Research area within the Research Division and added a new Strategic Facilities area within the Facilities and Projects Division.

[43]Department of Energy, Office of Science, *Building Bridges: A Bold Vision for the DOE Fusion Energy Sciences* (Washington, D.C.: June 2024).

building and leveraging external partnerships.[44] In particular, the objective on leveraging partnerships cited several examples of ongoing or potential fusion energy initiatives, including the Milestone initiative, FIRE Collaboratives, and the Public-Private Consortium Framework. DOE's strategy also identified commercialization risks that the agency should address, such as those related to manufacturing and supply chain, workforce, and community perception.

FES science and technology roadmap. FES is developing a fusion energy science and technology roadmap that is expected to focus on the initial steps to facilitate fusion energy commercialization.[45] FES documents characterized the roadmap as an interim product that would focus on closing science and technology gaps to enable demonstration of fusion pilot plants. FES has completed some inputs to the roadmap, such as hosting a workshop on the basic needs of inertial fusion energy in 2022 and producing a subsequent report in 2023.[46] According to a DOE official, as of September 2024 FES expected to complete the roadmap by the second quarter of calendar year 2025.

Although DOE has initiated planning efforts to facilitate fusion energy commercialization, it is uncertain whether DOE will sustain these efforts. For example, DOE officials told us the Net-Zero Game Changers initiative has been inactive recently and lacked future plans. OSTP officials told us they are no longer actively coordinating or hosting meetings. OSTP officials also told us that fusion energy technology is in the early stages and deferred to DOE on how to facilitate commercialization. The initiative's uncertain status indicates a risk of unclear roles and responsibilities for coordinating and planning interagency efforts. By specifying roles and responsibilities as part of its fusion energy planning efforts, DOE would be better able to coordinate its initiatives and leverage efforts of other agencies.

[44]Department of Energy, *Fusion Energy Strategy 2024* (Washington, D.C.: June 7, 2024). In an April 2024 public presentation, DOE officials announced they would develop a U.S. fusion energy strategy. The strategy was supposed to be a key output of the fusion crosscut team, which DOE formed in 2022, according to the team's charter.

[45]According to officials, the roadmap aims to address elements of the bold decadal vision and would build on prior reports and efforts from the National Academies and the Fusion Energy Sciences Advisory Committee. Officials told us that FES planned to develop a separate roadmap for plasma science and technology but did not specify a date.

[46]Department of Energy, Office of Science, *Inertial Fusion Energy: Report of the 2022 Fusion Energy Sciences Workshop on Inertial Fusion Energy* (Washington, D.C.: July 10, 2023).

Adoption Readiness Level Framework

In June 2023, DOE's Office of Technology Transitions developed an Adoption Readiness Level framework, which assesses the adoption risks of a technology and translates the risk assessment into a readiness score, representing the readiness of a technology to be adopted by the market. The framework considers subsequent elements of adopting a new technology across 17 dimensions of adoption risk, including the following:

Manufacturing and supply chain. The risk associated with manufacturing and supply chain may be assessed as low if deployment relies on off-the-shelf products or existing manufacturing capabilities. Conversely, the risk may be assessed as high if deployment requires creating new manufacturing processes or supply chain components, or if deployment will overwhelm existing supply chain capacities. As we reported in March 2023, limitations in the supply chain for semiconductors, rare earths, and helium could prevent the ability to build fusion energy systems at scale.

Workforce. The framework includes workforce as a risk and assesses whether the existing workforce has the necessary skills and training to design, produce, install, maintain, and operate the technology at scale. As we reported in March 2023, there is a shortage of fusion scientists, nuclear engineers, and electrical engineers. Training engineers, advanced technicians, and physicists takes many years, and funding and training opportunities are limited.

Community perception. Another risk is that of community perception, including the general perception by global and local communities of the technology solution and its risks or impact, either founded or unfounded. Fusion energy commercialization can be assessed by its likelihood that the public will either positively receive and support it, or that controversy could derail or significantly delay deployment. As we reported in March 2023, there are few studies about public perception of fusion energy.

Sources: Department of Energy (DOE) documents and GAO. | GAO-25-107037

Some DOE planning documents for fusion energy initiatives are incomplete. For example, according to DOE officials, DOE uses the Adoption Readiness Level Framework as a guide for fusion energy commercialization. However, DOE does not indicate with specificity or with timelines how it plans to respond to the risks it identified through the framework in its June 2024 strategy. DOE's strategy also does not translate its assessment of risks into a readiness score for adopting fusion energy technology, which DOE could use to better understand fusion energy commercialization risks. A DOE official told us that DOE will need to add details, such as metrics, in future documents. Without responding to identified risks as part of its planning efforts, DOE may not be prepared to address such risks if they materialize, potentially delaying commercialization efforts.

In September 2024, a DOE official announced that FES planned to complete and publish the roadmap in the second quarter of calendar year 2025. According to an April 2024 presentation from the Fusion Energy Sciences Advisory Committee, FES is waiting to finalize the roadmap until the committee completes its report on how FES can align its initiatives

with the March 2022 announcement.[47] The roadmap is to outline metrics and timelines against which DOE will measure its fusion energy initiatives related to science and technology. However, a DOE official told us that the roadmap would not address risks related to deploying fusion energy. The official told us that addressing risks would require a separate effort which DOE has not yet initiated.

DOE policy states that program plans should define program-specific goals and objectives, and identify the relationship between program objectives and an organization's strategy to clarify alignment to mission and leadership initiatives.[48] In addition, the policy states that roles and responsibilities for managers should be clearly defined, and risk management principles and practices should be implemented. As part of risk management, the policy states that DOE should identify potential risks and appropriately respond to those risks to enhance decisions and outcomes. However, DOE's planning to date, primarily through the FES Vision document and DOE's decadal fusion energy strategy, do not clearly define roles, respond to identified risks, or define metrics and timelines. Finalizing and implementing ongoing fusion energy planning efforts—whether through DOE's roadmap or some other vehicle—would better position DOE to make progress toward accelerating fusion energy commercialization and helping meet 2050 greenhouse gas reduction goals. Specifying roles and responsibilities, responding to identified risks, and detailing metrics and timelines would help DOE set realistic expectations and specific deliverables for facilitating fusion energy commercialization and inform further investment in public-private partnerships.

Conclusions

Fusion has the potential to be a critical low-carbon energy source for the U.S., but scientific research gaps and other risks remain. FES has led efforts to facilitate fusion energy commercialization, including an array of ongoing and planned initiatives with the private sector and universities to close the gaps needed to advance designs for a fusion pilot plant. DOE has also taken steps in response to the federal government's call in March 2022 to develop a decadal vision and strategy for fusion energy

[47]DOE asked the Fusion Energy Sciences Advisory Committee to reassess FES organization and its alignment with the advisory committee's 2020 report as well as OSTP and DOE's March 2022 announcement. This reassessment will also identify ways in which the agency could address near-term scientific and technological gaps that would affect the design and construction of a fusion pilot plant. The advisory committee's report is expected sometime in fiscal year 2025.

[48]*See* Department of Energy, *Program Management*, Policy 410.3 (Washington, D.C.: Sept. 23, 2021).

commercialization. However, it is unclear whether DOE will be able to sustain its planning efforts, some of which have lacked specific metrics and timelines. As DOE continues its planning efforts, providing realistic and specific goals, including metrics and timelines, for how DOE will facilitate commercialization is vital as the U.S. strives to build the first fusion pilot plant and begin adding fusion energy as another source of energy for the nation's electricity grid.

Recommendation for Executive Action

The Director of the Office of Science should finalize and implement ongoing fusion energy planning efforts, including by specifying roles and responsibilities, responding to identified risks, and detailing metrics and timelines for its initiatives. (Recommendation 1)

Agency Comments

We provided a draft of this report to DOE for review and comment. We received comments from DOE that are reprinted in appendix I. In its comments, DOE concurred with our recommendation. To address this recommendation, DOE stated that it would complete its fusion energy science and technology roadmap, which it expects to do by the end of the 2nd quarter of calendar year 2025, and take related actions. Collectively, the actions that DOE described, if implemented effectively, would address our recommendation. DOE also provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix II.

Sincerely,

Frank Rusco
Director, Natural Resources and Environment

Appendix I: Comments from the Department of Energy

Department of Energy
Office of Science
Washington, DC 20585

January 2, 2025

Mr. Frank Rusco
Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Mr. Rusco:

The Department of Energy (DOE) appreciates the opportunity to comment on the Government Accountability Office's (GAO) draft report titled, *Fusion Energy: Additional Planning Would Strengthen DOE's Efforts to Facilitate Commercialization (GAO-25-107037)*. The draft report contained a total of one recommendation; it was directed by GAO to DOE. DOE concurs with GAO's recommendation as detailed in the enclosure. DOE provides the following comments below.

The Office of Science (SC) Fusion Energy Sciences (FES) program is committed to a comprehensive planning effort, consistent with the DOE-wide "Fusion Energy Strategy 2024"[1] and the "Building Bridges" vision[2] for its FES program. The DOE-wide strategy, coordinated through the Office of the Under Secretary for Science and Innovation, is organized around three pillars to facilitate fusion commercialization: (1) resolving science and technology (S&T) gaps for commercially relevant fusion pilot plants; (2) preparing the path to sustainable, equitable commercial deployment; and (3) building and leveraging external partnerships. The FES Building Bridges vision supports all three pillars and, in particular, underpins pillar 1 of the DOE-wide strategy. Both documents were released in June 2024 and are consistent with the requirements and objectives of the Energy Act of 2020, the Fusion Energy Sciences Advisory Committee (FESAC) Long-Range Plan (LRP), and the National Academies report "Bringing Fusion to the U.S. Grid."

To support the FES strategic planning process, two FESAC charges were established in December 2023. First, the charge for Facilities Construction Projects focused on prioritization of facility projects that are aligned with the LRP priorities and address closure of S&T gaps in areas including fusion materials, blankets, and fuel cycle. The second charge, known as the FESAC Decadal Plan, focused on assessment of the alignment of selected FES programs with the FESAC LRP.

[1] Fusion Energy Strategy 2024
[2] FES Building Bridges Vision

Furthermore, FES is developing a National Fusion Science and Technology (FS&T) Roadmap, which focuses on closure of S&T gaps to commercially relevant fusion pilot plants. The FS&T Roadmap will guide a staged approach leading to a competitive fusion power industry, as mandated in the Energy Act of 2020 and the updated mission for the program.

To develop the FS&T Roadmap element of the strategic plan, information will be gathered from the FESAC charges described above, reports from over ten different technical community workshops on targeted fusion materials and technology areas, and Fusion Forums planned in late 2024 and early 2025. These forums will include discussions with key contributors to help assimilate all this information. Combined, this information will inform the National FS&T Roadmap, which will be a metrics- and schedule-driven plan that will enable long-term prioritization of research efforts to guide United States investments in fusion energy research and development toward demonstration and deployment. Completion of the Roadmap is expected by the end of the second quarter of calendar year 2025.

In addition, to support the "Building Bridges" vision, there has been a reorganization of both the FES budget and office structure. The budget restructuring supports a re-alignment of the FES program to better reflect the recommendations outlined in the FESAC LRP. The new office organizational structure consists of a new division entitled "Enabling Science and Partnerships." This division will oversee public-private partnerships and technology-inspired research programs.

GAO should direct any questions to Dr. Jean Paul Allain, Associate Director of Science for Fusion Energy Sciences, Office of Science, at (301) 903-4941 or jp.allain@science.doe.gov.

Sincerely

Harriet Kung
Deputy Director for Science Programs
Office of Science

Enclosure

Enclosure

Management Response
GAO Draft Report
Fusion Energy: Additional Planning Would Strengthen DOE's Efforts to Facilitate Commercialization (GAO-25-107037)

Recommendation 1: The Director of the Office of Science should finalize and implement ongoing fusion energy planning efforts, including by specifying roles and responsibilities, responding to identified risks, and detailing metrics and timelines for its initiatives.

DOE Response: Concur.

As described in the recently released Department of Energy (DOE) *Fusion Energy Strategy 2024*[1] and the *Building Bridges*[2] vision for the Office of Science Fusion Energy Sciences (FES) program, FES will develop a metrics- and schedule-driven National Fusion Science & Technology (FS&T) Roadmap that enables long-term prioritization of research efforts to guide United States' investments in fusion energy research and development toward demonstration and deployment. This National FS&T Roadmap will also identify various roles and responsibilities, within both the public and private sectors. Utilizing existing input from several sources, a series of Fusion Forums are planned in late 2024 and early 2025. The purpose of these forums is to assimilate information from recent community-led workshops, Fusion Energy Sciences Advisory Committee (FESAC) reports, and the draft technology roadmaps from awardees of the Milestone-Based Fusion Development Program. The first forum took place on December 4-5, 2024, in Washington, DC. It brought together public- and private-sector leaders of the community workshops and reports, as well as Milestone Program awardees, with a particular emphasis on identifying actions needed to address fusion materials and technology gaps. Future forums will focus on other priorities from the FESAC Long-Range Plan including development of specific metrics and system requirements to measure FES progress in addressing FS&T gaps and risks as well as gaps in sustaining burning plasmas. Output from these forums, together with FESAC reports including the Long-Range Plan, will provide input for the next steps in developing the National FS&T Roadmap.

Estimated Completion Date: DOE will complete the National Fusion Science & Technology Roadmap, to address this recommendation, by the end of the 2nd quarter of calendar year 2025.

[1] https://www.energy.gov/sites/default/files/2024-06/fusion-energy-strategy-2024.pdf
[2] https://www.energy.gov/sites/default/files/2024-06/fes-building-bridges-vision.pdf

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the contact named above, Matthew Tabbert (Assistant Director), Marie Bancroft (Analyst in Charge), Miguel Cortez Jr., Lily Folkerts, Frank Garro, William Gerard, Claire McLellan, Cynthia Norris, Dan C. Royer, Michael Smith, and Andrew Stavisky made key contributions to this report.