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Introduction

Chairman Manchin, Ranking Member Barrasso, and distinguished Members of the Committee, thank you for your longstanding support of fusion energy sciences research and development (R&D). As Associate Director for Fusion Energy Sciences (FES) in the Office of Science (SC), at the Department of Energy (DOE), it is an honor to provide testimony regarding DOE's recent efforts to accelerate progress on realizing the promise of fusion energy, in alignment with the Administration's *Bold Decadal Vision for Commercial Fusion Energy* (BDV)[1]. Simultaneously, we are also working to align with the recommendations of the Fusion Energy Sciences Advisory Committee (FESAC) Long Range Plan (LRP).[2] This past year, we have made tremendous progress. We have taken decisive action to realign the FES program to meet the rapidly changing fusion landscape, redesign and introduce innovative funding mechanisms in support of the expanded mission of the program, and deepen international partnerships with like-minded countries. All the while, we have maintained our focus on the important foundational science we steward for the nation.

I have had the privilege of working closely with the Department's Lead Fusion Coordinator and our talented staff to set clear goals for DOE's work on fusion energy sciences through the publication of two documents: the *Building Bridges* vision for FES, and the *U.S. Fusion Energy Strategy 2024*, which was recently released[3] at the White House event marking two years of the BDV.[4] My remarks today will focus on the specific role of the FES program within SC, but all of our work is in the context of the broader actions of the DOE as guided by the *U.S. Fusion Energy Strategy 2024*.

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[1] https://www.whitehouse.gov/ostp/news-updates/2022/04/19/readout-of-the-white-house-summit-on-developing-a-bold-decadal-vision-for-commercial-fusion-energy.

[2] Carter, T., Baalrud, S., Betti, R., Ellis, T., Foster, J., Geddes, C., ... & Rej, R. (2020). Powering the future: Fusion & plasmas. US Department of Energy (USDOE), Washington, DC (United States). Office of Science, https://science.osti.gov/-/media/fes/fesac/pdf/2020/202012/FESAC_Report_2020_Powering_the_Future.pdf

[3] https://www.energy.gov/articles/doe-announces-new-decadal-fusion-energy-strategy.

[4] https://www.whitehouse.gov/ostp/news-updates/2024/06/06/fact-sheet-biden-harris-administration-announces-more-than-180-million-to-advance-implementation-of-its-bold-decadal-vision-for-commercial-fusion-energy.

The promise of fusion energy cannot be understated. Harnessing energy from fusion reactions has the potential to address climate change by providing a sustainable and resilient *firm and carbon-free* source of energy, and also to provide the economic engine for the world's future energy sector supply chain. The combination of scientific support for fusion energy as well as basic plasma science research will also create spin-off plasma technologies that will benefit society, such as microelectronics production, material and chemical production, surface processing, and decomposition of wastes.

Further, because of the transformative potential of this technology, it is essential that we treat fusion energy also as a national security imperative. The United States cannot afford to have other nations surpass our technological leadership if we hope to own this technology into the future. ***To realize fusion in a decadal timeframe, we will need to take bold action to address the critical scientific and technological gaps that remain and establish the supply chains that will enable fusion energy at scale.***

At DOE, we are taking a multifaceted approach to realizing this vision, recognizing that no single government program will be able to translate fusion and make it competitive in future energy markets. This can be accomplished through three key steps:

1. ***Drive innovation and close key science and technology (S&T) gaps***. Investing in SC FES to align with recommendations of the FESAC LRP would accelerate advances at the necessary speed and scale.
2. ***Leverage Public-Private Partnerships (PPPs)***. Public-Private Consortium Frameworks enable participants from across the economy to support the development of fusion science and technology realizing commercial fusion energy. Participants might include academia, government laboratories, private equity, loan programs, state and regional governments, philanthropic investors, and large-scale industries and corporations.
3. ***Build a Robust Fusion Technology Manufacturing Network alongside partners***. This investment will produce innovations and scale essential fusion technologies—including internal components, advanced materials, and tritium management approaches—needed to make fusion economically competitive at scale.

Background

Over the past decade, the fusion energy R&D landscape has evolved significantly, especially in the U.S., building on decades of public investments in fusion S&T, major advances have been achieved both domestically and globally by public and private sector entities, such as the achievement of fusion ignition at the National Ignition Facility (NIF) at Lawerence Livermore National Laboratory (LLNL). These advancements are indications of fusion's increasing technological readiness. Major advances in related scientific fields, including high-temperature superconductors, advanced materials, exascale computing, and artificial intelligence/machine learning, have the potential to further accelerate and transform fusion R&D.

Currently, there is approximately $6.7 billion of cumulative equity investments in private fusion companies not including public investments.[5] While the shift toward greater private-sector

[5] *The Global Fusion Industry in 2024,* Fusion Companies Survey by the Fusion Industry Association, p. 5; available for download at https://www.fusionindustryassociation.org/fusion-industry-reports.

involvement in fusion R&D is seen most dramatically in the U.S., the trend can be observed globally, with equity investments into companies based in Canada, United Kingdom (UK), Japan, European Union (EU), China, and others. This trend is a strong indication of fusion's potential as a future commercial energy technology.

Within DOE, R&D in fusion energy is primarily funded through the SC's FES program. The mission of the FES program is to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundations needed to develop a fusion energy source. This is accomplished by studying the plasma state and its interactions with its surroundings.

Section 2008 of the Energy Act of 2020 amended the Department of Energy Research and Innovation Act (42 U.S.C. § 18645) to expand the scientific mission of FES by adding the goal of *"supporting the development of a competitive fusion power industry in the U.S."* Since then, a number of strategic documents have been produced to align the goals of the program, SC, and the Department with this expanded mission. In 2020, the FESAC released the LRP,[6] which provided SC with key recommendations and articulated that achieving a thriving and sustainable fusion energy industry of the future will require addressing key S&T gaps with a diverse set of tools and strategic approaches. The FESAC LRP became the blueprint from which a new SC FES program has been designed, complemented by the National Academies of Sciences, Engineering, and Medicine (NASEM) report on Bringing Fusion to the U.S. Grid[7] and the BDV. In combination, these documents help guide programmatic priorities and timelines to ultimately converge the interests of the public and private sectors in the U.S. to establish a robust fusion energy industry.

Following those reports, a new FES vision entitled *Building Bridges* was published in December 2023. This new vision focuses on aggressively closing the S&T gaps needed to realize commercial fusion energy in the three key scientific areas identified in the FESAC LRP and shifts the balance of research toward fusion materials and technology. The structure of the FES program was realigned this past year to better facilitate the new vision.

Lastly, the DOE *Fusion Energy Strategy 2024* was published in June 2024, in recognition of the crosscutting nature of the challenges we face to realize commercial fusion energy. The strategy consists of three primary pillars: 1) closing S&T gaps to commercially relevant fusion pilot plants; 2) preparing the path to sustainable, equitable commercial fusion deployment; and 3) building and leveraging external partnerships. While FES has a central role to play across these pillars, it will require the concerted effort of our partners across the Department and the interagency especially to prepare the path for sustainable and equitable deployment, which has supply chain, regulatory, and other key components that extend beyond SC's mission.

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[6] Carter, T., Baalrud, S., Betti, R., Ellis, T., Foster, J., Geddes, C., ... & Rej, R. (2020). Powering the future: Fusion & plasmas. US Department of Energy (USDOE), Washington, DC (United States). Office of Science, https://science.osti.gov/-/media/fes/fesac/pdf/2020/202012/FESAC_Report_2020_Powering_the_Future.pdf

[7] https://nap.nationalacademies.org/catalog/25991/bringing-fusion-to-the-us-grid

International Partnerships

Fusion has become a global race[8] and our ability to build partnerships in the public sector will be critical to the success of our fusion power industry. The United States has been a world leader in fusion R&D for the past four decades driven by the development of computational tools, large-scale experimental devices, and a scientific workforce with deep expertise and know-how. However, with the rise of globalization and scale of the challenges, it has become increasingly important to build partnerships with public and private entities in like-minded countries.

For DOE, this includes strategic international partnerships as part of a U.S. strategy for *International Partnerships in a New Era of Fusion Energy Development*,[9] which was announced at the 28th session of the Conference of the Parties (COP28) in 2023. This strategy will support the timely development, demonstration, and deployment of commercial fusion energy in strategic areas like research and development and harmonization of regulatory frameworks. For example, this past year, we have announced two strategic international partnerships with the UK[10] and Japanese[11] governments supported by coordinated teams representing our public and private sectors in fusion energy. We continue dialogue with additional like-minded nations, including Canada, Germany, France, and Korea, and continue to nurture our strategic relationship with the EU on fusion energy.

Another key example is our role in ITER, which is a multi-national collaboration to construct a complex scientific facility that will help usher an industrial-scale burning plasma experimental platform. ITER will be equipped with diagnostic capabilities that will not be built into a commercial fusion power plant. ITER will also be an experimental facility that will support fusion developers when fusion pilot plants are stood up in the future, as well as a multi-national supply chain supporting fusion energy development today. U.S. investments in ITER have yielded more than $1 billion in support for over 100 U.S.-based supply chain companies that are now becoming key contributors to the growing fusion industry while engaging with our public program. We continue to find ways to build bridges to ITER for both our private and public sector performers. The tremendous learnings to-date from the ITER project should be translated to the growing U.S. fusion industry.

DOE has also worked to build bridges between public and private sectors globally. One example is the work by Princeton Plasma Physics Laboratory (PPPL) and Oak Ridge National Laboratory (ORNL) with the UK-based Tokamak Energy company. This collaboration enabled their compact spherical tokamak device (ST-40) to demonstrate temperatures greater than 100-million degrees, providing the heat required to scale towards commercial fusion energy production.

***Building Bridges* Report and the Vision for the FES Program**

The future of the FES program will be guided by the vision outlined in the *Building Bridges* report. The three key elements of the FES vision are:

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[8] G. Conroy, *Inside China's race to lead the world in nuclear fusion,* News Feature, Nature, 28 August 2024.
[9] https://www.whitehouse.gov/ostp/news-updates/2023/12/02/international-partnerships-in-a-new-era-of-fusion-energy-development.
[10] https://www.energy.gov/articles/joint-statement-between-doe-and-uk-department-energy-security-and-net-zero-concerning.
[11] https://www.energy.gov/articles/joint-statement-between-doe-and-japan-ministry-education-sports-science-and-technology.

- ***Workforce Development and Sustainment:*** Ensuring establishment of sustainable and resilient pathways for diverse and exceptional talent.
- ***Bridging Gaps:*** Creating innovation engines with national laboratories, universities, and industry to support science excellence and technology readiness for fusion energy.
- ***Transformational Science:*** Nurturing plasma science and technology discovery translating to innovation impact.

To achieve this vision, FES is taking action to build a U.S. fusion S&T roadmap aligned with the fusion industry, create new innovative funding mechanisms that can build and deepen public-private partnerships, and realign the structure of the program to better support its goals.

Developing a national fusion S&T roadmap aligned with industry: FES is developing a metrics-driven national fusion S&T roadmap that informs decision-making on the "how" and "when" (including facility needs) of closing the critical S&T gaps. The roadmap is being developed in part based on output from a series of community workshops held from 2022–2024 that were focused on several critical areas, including public-private partnerships in fusion energy R&D; inertial fusion energy; updating the requirements for a fusion prototypic neutron source (FPNS) and other large-scale fusion materials and technology facilities; fusion neutronics; magnet technology; fuel cycle and blankets; fusion materials; measurement innovation; and fusion workforce development. The roadmap will be unique because it will align government research with the fusion industry and ensure that FES is guided by innovation principles that bridge foundational research with user-inspired and user-defined goals.

Bridging gaps through the FIRE Collaboratives: To resolve S&T gaps to a commercially relevant, private sector-led fusion pilot plant and to support the creation of a fusion innovation ecosystem, the new FES FIRE Collaboratives program will consist of virtual, centrally managed teams (led by national laboratories and/or universities) called "Collaboratives." This program bridges FES's foundational and enabling S&T research programs to the work and needs of the growing fusion industry. Moreover, this initiative aims to create new economic opportunities, bolster U.S.-based manufacturing and supply chains, and enable the development of technologies that are also crucial for national security, defense, and other commercial industries.

Leveraging public-private partnerships: Public-private partnerships (PPP) will be employed as a key enabler of the DOE fusion strategy to accelerate the R&D needed to close S&T gaps to a fusion pilot plant and to achieve the pace required to meet the timeline of the BDV. Examples of recent and ongoing fusion PPP programs include the ARPA-E fusion capability teams, the FES Innovation Network for Fusion Energy (INFUSE), and the FES Milestone-Based Fusion Development Program ("Milestone Program").[12, 13, 14]

DOE has made significant progress in implementing the new Milestone Program over the past year. Through this program, we have signed highly flexible Technology Investment Agreements (TIAs) with eight companies, which are already beginning to deliver on their milestones. The

[12] https://www.energy.gov/science/articles/department-energy-announces-50-million-milestone-based-fusion-development-program.
[13] Funding opportunity announcement (FOA): https://science.osti.gov/grants/FOAs/FOAs/2022/DE-FOA-0002809.
[14] The Milestone Program supports a variety of fusion approaches at different technological readiness levels, which is a feature adopted from the DOE Nuclear Energy Advanced Reactor Demonstration Program.

awardees have collectively closed additional private funding rounds totaling more than $200 million since the announcement of their selections in the Milestone Program, validating one of the policy objectives of the program to significantly amplify federal funding in support of fusion energy commercialization. While DOE intends to continue streamlining our processes for partnering with the private sector, we are also in a good position to build on the precedent of these TIA terms and conditions for other innovative fusion public-private-partnership programs in support of the DOE fusion strategy and the U.S. Bold Decadal Vision.

To take these program innovations yet further, FES issued a Request for Information (RFI) to inform the establishment of a Public Private Consortium Framework (PPCF) that will bring the broad community together to advance the research, development, demonstration, and deployment (RDD&D) of commercial fusion energy. Complementary to the Milestone Program and Fusion Innovation Research Engine (FIRE) Collaboratives (discussed further below), a PPCF could amplify federal funding by catalyzing and bringing together state/local government, private, and philanthropic funding to resolve significant, remaining S&T gaps (with an emphasis on pre-competitive R&D and aligned with technology roadmaps of private-sector fusion developers and critical supply-chain providers) and to deliver essential small-to-medium scale R&D test capabilities. If built around regional hubs, such an effort could also stimulate distributed development of fusion supply chains and workforce and support regional economic development and community engagements. The DOE Foundation for Energy Security and Innovation[15] (FESI) could be a potential vehicle for convening non-Federal partners and launching a fusion PPCF.

Conclusion

We are in one the most consequential moments for the development of fusion energy. Translating this technology to a global competitive resource will require significant investment and effort. History has taught us the magnitude and scale of translating hard technologies, e.g., from the 12-second, 120-foot first flight in North Carolina to realizing that first step on the moon's surface resulting in commercial flight and the space age, respectively. Realizing fusion energy may be at least as challenging, we at DOE are up to this challenge. As one of the universe's most efficient and powerful energy resources, fusion energy is a mandate we must realize for our clean energy and economic goals and to ensure U.S. technological leadership this century and beyond.

[15] https://www.energy.gov/articles/doe-launches-foundation-energy-security-and-innovation.