# Testimony before the U.S. Senate Committee on Energy and Natural Resources

## Full Committee Hearing to Examine Fusion Energy Technology Development


Testimony of Dr. Patrick White

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Chairman Manchin, Ranking Member Barrasso, and members of the Committee:

Thank you for the opportunity to testify today before this Committee and for holding this hearing. My name is Dr. Patrick White, and I am currently the Research Director for the Nuclear Innovation Alliance (NIA). NIA is a 501(c)(3) organization focused on creating the conditions for success for advanced nuclear energy as a climate solution. I hold a PhD in Nuclear Science and Engineering from the Massachusetts Institute of Technology, where my doctoral thesis work focused on the safety analysis, regulation, and licensing of commercial fusion technology.

NIA is partnering with the Clean Air Task Force (CATF) on independent research, analysis, and stakeholder engagement to support the commercialization and deployment of fusion energy around the world as a key clean energy source. CATF also is a 501(c)(3) organization working to rapidly reduce emissions while advancing bold, durable climate solutions to ensure a net-zero emissions, high energy planet at an affordable cost. Both NIA and CATF provide independent technical research, analysis, and advocacy to help advance policies and technologies that enable deployment of clean energy solutions to meet our economic, societal, and climate needs.

In early 2023, CATF created the Global Programme on Fusion Energy. Through the NIA-CATF partnership and within the Global Programme on Fusion Energy, I lead the CATF International Working Group on Commercial Fusion Energy Safety, Waste, and Non-Proliferation. The CATF Programme, led by Dr. Sehila M. Gonzalez de Vicente, is focused on paving the way towards commercial fusion energy and is organized around clarifying technology development pathways for fusion energy, de-risking the regulation and commercialization of fusion energy projects, supporting emerging commercialization pathways for fusion technology, and setting up the global case for fusion energy deployment.

I am here today to provide insights on the development and deployment of fusion energy technology as an important future clean energy source.

**Introduction**

The development, commercialization, and deployment of fusion energy technology has been a dream of scientists and engineers for decades. In 1951, the U.S. Atomic Energy Commission initiated Project Sherwood to coordinate national research efforts on controlled fusion in the United States. Generations of scientists and engineers have worked over the past seven decades to develop fusion machines that could control and harness one of the fundamental sources of energy in the universe.

We have made incredible advances since the earliest days of fusion energy research, and progress on fusion energy is accelerating. This year experimental fusion machines such as the Joint European Torus (JET) in the UK set records on total energy generation from a controlled plasma[1] and the WEST fusion machine in France set records for the continuous control and confinement of a high-temperature plasma.[2] And since December 2022, the National Ignition Facility (NIF) has been able to repeatedly demonstrate net energy gain, commonly described as scientific breakeven, from an inertially confined fusion reaction.[3] These experiments and others that are currently under way in the United States and around the world are providing scientific insights critical to controlling fusion energy.

Private companies are also now playing a significant role in the research and development of fusion energy. For decades, federally supported fusion energy programs at national labs and universities have played a leading role in fusion energy. Major fusion experiments such as the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Lab (PPPL), Alcator C-Mod at the MIT Plasma Science Fusion Center (PSFC), and DIII-D still operated today by General Atomics in San Diego provided scientific insights on the control of fusion energy. Building on decades of publicly funded fusion research and catalyzed by developments in enabling materials and components, novel fusion machine designs, and state-of-the-art computation analysis and control methods, private companies are leading in the United States on the development of fusion energy machines. These companies, funded by private investors and industrial partners, are working to create fusion machines capable of producing the energy that can help us meet our nation and our world's need for clean, reliable, and affordable energy. The Fusion Industry Association reported that total private investment for fusion energy companies exceeded $7 billion in 2024.[4]

Recent progress on both fusion energy research and private company developments are worth celebrating. And while we have passed several important milestones in the development and commercialization of fusion energy, it's important to contextualize and discuss the pathway and future milestones that still lie ahead for fusion energy. A clear understanding of the milestones, timing, and challenges on the pathway to global fusion energy enables us to discuss how we can most effectively catalyze and accelerate the development, commercialization, and widescale deployment of fusion energy.

**Goals of fusion energy development and deployment**

The goal of fusion energy development, commercialization, and deployment efforts is largely the same now as it was at the start of Project Sherwood in 1951: to control and harness fusion reactions. The impetus for fusion energy development efforts in the United States and

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[1] JET's final tritium experiments yield new fusion energy record - GOV.UK (www.gov.uk)
[2] Fusion record set for tungsten tokamak WEST (phys.org)
[3] Momentary Fusion Breakthroughs Face Hard Reality (spectrum.ieee.org)
[4] 2024 Annual Global Fusion Industry Report (fusionindustryassociation.org)

around the world, however, has evolved with our changing views on how we produce and use energy to maximize the benefit to society. Today we recognize that access to clean, reliable, affordable, and secure energy is critical to improving the quality of life of people in the United States and around the world.

Studies by energy system researchers and grid operators show that an energy system that consists of only variable clean energy sources (such as solar and wind) and energy storage (such as battery storage) may be much less reliable and much more costly than energy systems that include firm clean energy sources.[5] Firm clean energy sources are generation technologies that can produce clean energy when it's needed and complement variable clean energy sources to meet system demand. Examples of firm clean energy sources currently used or under development include hydroelectric power, nuclear fission energy, geothermal energy, and natural gas with carbon capture and storage.[6]

Commercial fusion energy could play a significant role in future clean energy systems as a firm clean energy source and would complement other firm-clean energy sources. Fusion machines may not have the same geographic and geologic limitations as hydroelectric, geothermal, and natural gas with carbon capture and storage, enabling widescale deployment in the United States and worldwide. Fusion machines may not have the same geopolitical, safety, and export concerns as nuclear fission energy and could be deployed more easily in countries with and without prior commercial and regulatory experience with nuclear fission energy. Deployment of commercial fusion energy at scale could help enable the United States and other countries around the world to generate the vast amounts of reliable and affordable clean energy needed to meet our climate and economic goals.

Successful development, commercialization, deployment, and export of commercial fusion energy by the United States will have additional societal, economic, and geopolitical benefits. Research and development in enabling technologies for fusion energy will likely produce new discoveries in materials science, high-energy systems and controls, and healthcare. Developments such as lower cost and higher performance high-temperature superconducting magnets for different industrial applications[7], power management systems and storage for clean energy systems[8], and new radioisotope therapies for cancer and other medical diagnostics and treatments[9] are just a few of the innovations that may be unlocked as we develop the enabling technologies for fusion energy. The economic benefits from an on-shored supply chain for fusion technology and deployment of hundreds or

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[5] The Role of Fusion Energy in a Decarbonized Electricity System (mit.edu)
[6] Review and Assessment of Literature on Deep Decarbonization (catf.us)
[7] HTS Magnets (cfs.energy)
[8] TAE Power Solutions (tae.com)
[9] Producing Medical Isotopes Lu-177 and Mo-99 (shinefusion.com)

thousands of fusion power plans would have economic benefits for workers across the country. And export of U.S. fusion technology abroad will help countries meet their clean energy goals, increase standards of living, and improve energy security.

The question that we need to address is how we can create a pathway from the fusion energy research and commercial developments underway today to a future where fusion plays a significant role in global clean energy production.

**Development phases and milestones for commercial fusion energy**

Clear performance milestones for commercial fusion energy development can help us assess the wide variety of different fusion energy concepts currently under development and prioritize federal support. Different approaches to fusion energy may have different scientific or engineering metrics that most accurately characterize technology development. Metrics such as plasma confinement time, plasma temperature, pulse time, pulse rate, peak magnetic field, fusion energy production, and net energy production are all examples of metrics that can be useful to scientists and engineers when researching, developing, and testing fusion machines. These metrics, however, are not always comparable across different fusion machines or technologies and can be challenging for policymakers and the public to accurately assess and compare. Even the relatively simple metric of the fusion energy gain factor from a fusion machine, typically termed "Q", can be misinterpreted if a project does not specific how it is defining or using the metric.[10]

The specific operational characteristics, designed capabilities, and planned mission of a fusion machine will vary on a project-by-project basis, but four typical development phases can be defined for the commercialization of fusion energy. These four development phases define key transition points in the development and commercialization of fusion energy technology and enable more meaningful comparison between the fusion energy concepts at different phases of development. The four development phases are (1) scientific demonstration, (2) engineering demonstration, (3) commercial demonstration, and (4) commercial deployment.

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[10] The fusion energy gain factor, "Q", is typically defined as the ratio of the energy released from fusion reactions to the energy input into a fusion reaction, experiment, or machine. If the Q value is equal to or greater than 1, the system is described as having achieved "breakeven" because the experiment has produced as much energy as it consumed. Some scientists and engineers, however, will discuss fusion energy gain factors differently depending on how they define the amount of energy used to power the fusion machine or experiment. Two common fusion energy gain factors, "scientific energy gain"/"scientific breakeven" and "engineering energy gain"/"engineering breakeven", are described in more detail in footnotes 11 and 12 . Please see Progress toward fusion energy breakeven and gain as measured against the Lawson criterion (aip.org) for addition discussion.

Scientific demonstration of fusion energy is the operation of a fusion machine that demonstrates and tests the generation, control, and confinement of plasmas. These machines are focused on developing and mastering control of fusion energy and may only operate for short periods of time or with a focused scientific mission. This phase of operation may be defined by technical milestones such as achieving scientific breakeven (net energy gain from a fusion reaction)[11] for fusion energy, and demonstrating sustained plasma control and confinement for a specific technology or design.

Engineering demonstration of fusion energy is the operation of a fusion machine that demonstrates and tests integration of plasma systems with new systems required for continued or repeated operation of a fusion machine. This can include new fusion fuel cycle systems, systems that can capture energy from fusion reactions, or improved plasma generation, control, and confinement systems. These machines are focused on developing the engineered systems to harness fusion energy and may or may not demonstrate production of electricity or other energy products. This phase of operation may be defined by technical milestones such as achieving engineering breakeven (e.g., net system energy gain from a fusion machine)[12] and demonstrating a sustainable fusion fuel cycle for a specific technology or design. The engineering demonstration may be capable of producing net electricity for the grid but may not operate commercially or with high commercial availability. The 2020 Fusion Energy Sciences Advisory Committee (FESAC) definition of a "fusion pilot plant" generally aligns with this engineering demonstration phase.[13]

Commercial demonstration of fusion energy is the operation of a fusion machine that demonstrates and tests integration of all fusion energy systems required to produce energy commercially. This includes integration of electricity or energy product generation systems, fusion fuel cycle systems, and other auxiliary systems with the fusion power systems. These

[11] "Scientific gain" is defined as the ratio of energy produced by fusion reactions to energy input required to produce a fusion reaction, typically by external heating of the fusion fuel. "Scientific breakeven" occurs when the "scientific gain" is equal to 1 – i.e., the amount of fusion energy produced by the reaction is equal to the amount of energy required to heat the fusion fuel to create the fusion reaction. "Scientific gain" and "scientific breakeven" do not account for any energy losses or inefficiencies in fusion machine systems.

[12] "Engineering gain" is defined as the ratio of energy produced by a fusion energy system to total energy input required to operate a fusion energy system. "Engineering breakeven" occurs when the "engineering gain" is equal to 1 – i.e., the amount of fusion energy produced by a fusion energy system is equal to the total amount of energy required to the operate the fusion energy system. "Engineering gain" and "engineering breakeven" account for the energy losses or inefficiencies in fusion machine systems and describe when a fusion energy system could begin to produce overall net energy. A fusion energy system that achieves "engineering breakeven" will have a "scientific gain" much higher than 1 because the calculation of "scientific gain" does not account for energy losses or other inefficiencies in fusion machine systems.

[13] Powering the Future: A Report of the Fusion Energy Sciences Advisory Committee (osti.gov)

machines would demonstrate that fusion energy is a commercially viable technology. This phase of operation may be defined by technical milestones such as achieving commercially relevant net energy production from fusion reactions (e.g., typically producing tens to hundreds of megawatts of net fusion power for most private concepts[14]) and demonstrating reliable integrated system operation. The EUROfusion program definition of a "demonstrate power plant" or "EU DEMO" generally aligns with this commercial demonstration phase.[15]

Commercial deployment of fusion energy is the deployment of fusion machines that can be operated to produce clean, reliable, and economically competitive energy. While fusion energy machines will continue to improve over time with increased operating experience and design optimization, commercially deployed fusion energy machines would signify the emergence of commercial availability of fusion energy as a viable firm, clean energy source. This phase of operation may be defined by socio-techno-economic conditions such as cost-competitive production of fusion energy (e.g., competitive with other firm, clean energy sources) and socially acceptable deployment of fusion energy globally (e.g., sustainable, geopolitically accepted deployment and operation).

Completion of all four development phases (and the associated technical milestones) is necessary for the realization of fusion energy as a future clean energy source. It is important to note, however, that there are multiple strategies to complete the four phases. Some private fusion energy companies may plan to build separate fusion machines for scientific, engineering, and commercial demonstrations, taking a more iterative approach to development (with completion of phases occurring in series or overlapping in parallel). Other programs may seek to combine one or more of their demonstrations into a single fusion machine and take a more accelerated approach development by demonstrating and testing multiple systems simultaneously. Different development strategies will have commercial benefits and risks that depend largely on the fusion energy technology, specific design, and company priorities. These different development strategies can also be accelerated by different types of government support.

**Assessing development phases and milestones for commercial fusion energy**

Each of these development phases has different challenges that we will need to identify, address, and overcome for us to achieve our goal for fusion energy to play a significant role in global clean energy production. Any fusion energy technology that will play a meaningful role in clean energy production will have to progress through each of these phases from research and development through commercialization. Some fusion energy technologies, however, may not be able to successfully commercialize for a variety of scientific, technical,

[14] 2024 Annual Global Fusion Industry Report (fusionindustryassociation.org)
[15] DEMO - EUROfusion (euro-fusion.org)

social, political, or economic reasons that are not yet known. But it's nearly impossible at this time to know with any certainty which technologies or companies will succeed. It is up to private fusion companies to demonstrate their specific designs and approaches.

Commercial deployment of any fusion energy technology will require multiple scientific and engineering breakthroughs to enable the control and harnessing of fusion energy. Prediction of these breakthroughs is challenging at best given our limited testing and operating experience with key emerging technologies, including enabling materials and systems, novel fusion machine designs, and state-of-the-art computation analysis and control methods. Supporting and promoting technology innovation by commercial fusion energy companies through public and private efforts will be key to the successful deployment of fusion energy as a clean energy solution.

**Key activities to enabling commercial fusion energy development and deployment**

It is important that we support and promote innovation in fusion energy development and commercialization and assess the progress of commercial fusion development on milestone-based pathways. This also, however, requires that we are pragmatic with federal support for commercial fusion energy and that we intentionally prioritize key activities needed to enable the widescale deployment of commercial fusion energy including:

- classifying and prioritizing gaps in fusion material science knowledge and enabling technology readiness to focus cross-cutting public and private technology research and development,
- identifying and planning for critical mineral supply, manufacturing supply chain, and workforce needs for the domestic production, manufacturing, construction, and deployment of commercial fusion energy systems,
- assessing and minimizing the potential safety hazards for future fusion machines that may look different from the scientific demonstrations currently under development today and ensuring effective, efficient and appropriate regulations,
- characterizing and managing the potential radioactive byproducts and wastes that could be produced by commercial fusion energy deployed at scale,
- understanding and mitigating any potential non-proliferation risks posed by fusion technology, and
- understanding and addressing potential siting, operational, or energy system integration challenges for fusion energy technology as a part of future electrical and industrial clean energy systems.

These key steps can be challenging to discuss because the importance of these steps for fusion energy technology will vary both over time and between private companies. First, some activities may not be relevant to all fusion energy technologies depending on the specific technology, design, or fuel cycle. Second, some activities may not be relevant to the near-term development of fusion energy as private companies construct and operate their scientific and engineering demonstrations. Third, fusion energy companies will play a major role in determining the significance of different steps through their technology, design, and operating choices and tradeoffs. Companies should assess these tradeoffs at the early stages of fusion technology development. Fourth, many activities are related to the societal acceptance of fusion energy technology and a broader understanding of different tradeoffs related to the benefits and costs of all energy production technologies.

Some activities may ultimately not require any actions depending on the results of technical and policy assessments or be relevant to the fusion energy technologies that are commercially deployed. Other activities may not be relevant in the near term for scientific and engineering demonstrations or even for limited domestic commercial deployment but should be considered for widescale domestic and global deployment of fusion energy. If we do not proactively address these key steps, especially those requiring significant time or resources to address, we may delay the successful commercial deployment of fusion energy. And until we accurately assess these potentially important activities, we will not know which activities could inhibit or delay the deployment of commercial fusion energy.

We also need to expect transparency and accountability from private companies when it comes to development of their fusion energy technologies. As Dr. Bob Mumgaard, CEO of Commonwealth Fusion Systems (CFS), recently wrote in an open letter entitled "Building Trust in Fusion Energy"[16]:

*"The industry must not give into marketing hype. We must communicate clearly, openly, and accurately with investors, regulators, policymakers, and the general public."*

I strongly agree with Dr. Mumgaard's statement. Discussions of the benefits and challenges of fusion energy commercialization should be clear. It is important to avoid overly broad or technically accurate but colloquially misleading statements. While this type of messaging may help in the near term with public relations or be used to clearly differentiate fusion energy from other technologies such as nuclear fission, public trust lost from promises made and promises broken will be much more challenging to regain.

Fusion energy's success depends on its merits as a safe, clean, firm energy source that will help the United States and countries around the world meet their energy needs. And with a common understanding of the pathways for fusion energy development and

[16] Building Trust in Fusion Energy | Commonwealth Fusion Systems (cfs.energy)

commercialization (as well as the key steps to fusion energy deployment), we can now discuss how the United States should accelerate the pathways to commercial fusion energy.

**Accelerating the pathways to commercial fusion energy**

Private commercial fusion energy companies are leading the commercialization and deployment of fusion energy in the United States. New approaches to fusion energy, catalyzed by technological innovations, are creating faster pathways to fusion energy deployment. Private commercial fusion energy companies in the United States must take a leading role in the development and commercialization of fusion energy, but the federal government can play an important role in accelerating pathways to commercial fusion energy deployment.

The first step on the pathways towards commercial fusion energy is demonstrating controlled fusion energy and achieving scientific breakeven. Private companies are in the best position to lead, and many companies have already announced plans to demonstrate controlled fusion energy. Helion is constructing their *Polaris* fusion generator in Washington State[17], CFS is constructing their *SPARC* fusion machine in Massachusetts[18], and Type One Energy has announced plans to build their *Infinity One* fusion machine in Tennessee[19]. These activities have been made possible by private investment and the regulatory certainty provided by the U.S. Nuclear Regulatory Commission on the licensing of fusion technology under the byproduct materials licensing framework.[20] This work could be further accelerated by federal support that facilitates rapid public-private partnerships to access federal research and testing facilities, as well as enable access to important international scientific collaborations. For these companies, speed is key. We need to improve DOE solicitation, evaluation, and contracting so we can measure the time required to solicit and distribute federal program contracts for fusion in weeks and months and not in months and years.

The second step on the pathways towards commercial fusion energy is demonstrating fusion energy engineering and achieving engineering breakeven. Engineering a fusion machine requires the development, testing, and demonstration of new systems and components that can help control and harness fusion energy. Private companies are best positioned to lead and the diversity of fusion energy technologies currently under development by private companies makes federal support for any single technology risky. Continued use of a milestone-based support program can help the DOE prioritize private company support of multiple fusion energy concepts while ensuring effective use of federal funds.

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[17] Helion Polaris (helionenergy.com)
[18] CFS SPARC (cfs.energy)
[19] Type One Energy Infinity One (typeoneenergy.com)
[20] NRC to Regulate Fusion Energy Systems Based on Existing Nuclear Materials Licensing (nrc.gov)

The federal government can help significantly accelerate fusion energy development by supporting enabling technologies for fusion energy. Key engineering-relevant fusion energy technologies needed by many different private companies (such as fusion fuel cycle systems or tritium-related technology) require substantial research and development work. These industry cross-cutting activities require specialized knowledge and facilities to efficiently complete. Federal prioritization and support for industry-wide research and development activities by national labs or private companies on enabling technologies could help reduce the cost and accelerate the development of engineering demonstrations. Shortening schedules and maximizing the impact of federal funding is key. It is critical to have efficient award and contracting processes so that companies are not spending years finalizing relatively small amounts of federal support.

The third step on the pathways towards commercial fusion energy is demonstrating and harnessing fusion energy commercially. While we understand the general activities needed to complete this step of the pathway towards commercial fusion energy, the specific timing and needs of private industry are less clear. The success of private companies demonstrating scientific and engineering breakeven for fusion energy in the coming years will affect the technical and commercial priorities for the industry. Again, federal prioritization and support of cross-cutting research and development could help accelerate the commercialization of fusion energy. Specifically, funding or facilitating national testing capabilities for the development and testing of new materials for fusion energy and enabling technologies for commercial fusion energy systems will help benefit all U.S. private fusion energy companies. These research programs will take several years to get organized and begin producing meaningful data, so it is important that we start now to help create the future conditions for success for commercialization of fusion energy. It will also be important to collaborate with the commercial fusion industry to identify how the federal government can most effectively and efficiently help reduce the financial risk of commercial demonstrations and accelerate commercialization through public-private partnership or other milestone-based programs.

The fourth and final step on the pathway towards commercial fusion energy is deployment of fusion energy at scale as a clean energy source. We need to consider what it will take for fusion energy to deploy rapidly as a commercially viable source of clean energy. The most important step we can take for the widescale deployment of fusion energy is to ensure that the policy incentives available for other clean energy sources (including production tax credits, investment tax credits, and loan guarantees) are also made available for commercial fusion energy. A level playing field will enable commercial fusion energy to compete with other clean energy sources based on its economic and technical merits, and signal that fusion energy is a technology that can play a major role in our future clean energy system.

Fusion energy deployment will depend on the technology and business case for individual private companies, but several important activities should be addressed through partnerships between private companies and the federal government. Private industry will need to develop and optimize critical fusion energy systems and technologies for commercial fusion energy deployment (including fusion material development, sustainable fusion fuel cycles, and power generation systems) and can be accelerated by federally supported research facilities. Industry and government will need to ensure that the regulatory frameworks in place for the near-term deployment of fusion energy will be appropriate and can scale in the United States and around the world to ensure effective and efficient regulation of safe fusion energy. Industry should identify opportunities to lead on development of a robust supply chain and work force for fusion energy including raw materials (e.g., rare earth elements), manufactured components, and different segments of the future fusion energy workforce including construction and manufacturing, technicians, operators, scientists, engineers, and radiation protection professionals all with knowledge of fusion energy. The federal government can play a critical role in catalyzing private investments. Finally, we will need to enable the export of U.S. fusion technology around the world by creating effective codes, standards, and harmonized regulation and export controls that help ensure the safe, economically competitive, and fair deployment of fusion energy.

**Comparison case study: Chinese commercial fusion energy development**

It is important to note that the United States is not the only country working to develop and deploy commercial fusion energy technology. The United Kingdom, European Union (particularly Germany), and China all have substantial public and private programs to control and harness fusion energy. In Hefei, China, the Chinese Academy of Science's Institute of Plasma Physics is coordinating and directing billions of dollars of research and development each year on commercial fusion energy. China's scientists and engineers are already operating the Experimental Advanced Superconducting Tokamak (EAST), one of the leading experimental fusion machines in the world.[21] They are already constructing Burning Plasma Experimental Superconducting Tokamak (BEST) which is designed to serve as both a scientific and engineering demonstration machine – testing key fusion fuel cycle and tritium components for fusion energy – in China in three to five years.[22] The China Fusion Engineering Test Reactor (CFETR) is currently being designed and will be their first commercial demonstration machine in the 2030s as they envision widescale commercial deployment in the following decade.[23] They're also building enabling technology research facilities to help accelerate development. The Comprehensive Research Facility for Fusion

[21] Inside China's race to lead the world in nuclear fusion (nature.com)
[22] Controlled nuclear fusion emerges as new frontier for China's venture capitalist (news.cn)
[23] Building Bridges: A Bold Vision for the DOE Fusion Energy Sciences (osti.gov)

Technology (CRAFT) will be completed in 2025 and will enable and accelerate technology development to support their scientific, engineering, and commercial demonstrations.[24] Simply put, China has a plan for all phases of the fusion energy commercialization pathways and they are making investments to accelerate development and future deployment.

The United States needs to consider what role we want to play in the global race for fusion energy. Fusion technology innovation by private companies in the United States is unmatched, but we need to ensure they have the support and policy clarity to compete and win internationally against state-owned or state-supported fusion energy programs. Maintaining a clear plan across the entire federal government for the commercialization and deployment of fusion energy can help catalyze private investment in fusion energy companies. Federal support, coordination, and de-risking of commercial projects using cross-cutting fusion energy technology research and development programs can help accelerate fusion commercialization and free up important private investment for other development activities. Creating, maintaining, and implementing a roadmap for both private companies and federal support for the development and deployment of commercial fusion energy is critical to unlocking American competition and innovation, and enabling the United States to compete internationally to supply clean, safe, and affordable fusion energy.

**Next steps on commercializing fusion energy**

In closing, fusion energy can play a major role in our nation and our world's future clean energy system. Accelerating the commercial development and deployment of fusion energy will require investment by the private sector and continued coordination and support from the federal government. Two major factors should be prioritized as we work toward commercialization of fusion energy. First, we need to ensure that clean energy policies are technology-inclusive policies to create a market pull for fusion energy as a firm, clean energy source. Second, private companies, researchers, and the federal government should closely coordinate and collaborate to most effectively and efficiently prioritize efforts to accelerate fusion energy commercialization. Public and private partners should collaborate to:

- coordinate and intentionally prioritize federal support for fusion science research and fusion energy research and development with a focus on fusion commercialization
- evaluate and hold fusion development programs to milestones that are clear and realistic (in terms of both achievability and timing) to enable competition amongst a wide range of different fusion energy technologies and companies
- prioritize federal support for cross-cutting technology research and development programs that can help accelerate progress across private companies toward

[24] China Sets to Build Fusion Energy Research Facility (cas.cn)

commercial deployment at scale, with a focus on technically and economically viable pathways to fusion energy

- facilitate international collaborations so that we can most effectively engage with our allies on common research and development programs that help provide critical scientific and engineering data for private companies
- evaluate and address any safety and environmental impacts, byproduct and waste management, non-proliferation, and export controls concerns to enable the deployment and export of fusion energy at scale around the world.

These collaborations will help maximize the impact of federal investments in fusion energy research and development, multiply the impact of private investment on fusion energy technology commercialization, accelerate commercial development and deployment of fusion energy, and help us realize the climate, societal, economic, and geopolitical benefits of fusion energy as a key part of our clean energy future.