Testimony of Professor Steven Cowley, Director, Princeton Plasma Physics Laboratory
U.S. Senate Committee on Energy and Natural Resources
"The Federal Government's Role in Supporting the Commercialization of Fusion Energy"

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Chairman Manchin, Ranking Member Barrasso, and Committee members,

Thank you for the invitation to testify today. I am the Director of the Princeton Plasma Physics Laboratory (PPPL) and a professor of astrophysics at Princeton University. Princeton manages PPPL, which is the lead Department of Energy National Laboratory for fusion research and plasma physics. The entire fusion community is deeply grateful to this Committee for its long-standing commitment to the development of fusion energy. It is an honor to appear before you.

First, what is fusion energy? It is the power source of our sun and, indeed, all the stars of the universe. It is the process of fusing small atoms, like hydrogen, to make bigger atoms and release energy. Indeed, the sun has shined for 4.6 billion years powered in its core from the fusion of hydrogen to make helium.

Fusion is, in many ways, the "*perfect energy source*." It is safe and clean (it has no greenhouse gas emissions and no long-term radioactive waste). The fuel we need for fusion is extracted from sea water. It is abundant and sustainable for millions of years. But fusion requires extreme conditions – astonishing temperatures above 100 million degrees centigrade.

So, *is it even possible to do fusion on earth?* The answer is clearly, "yes." As far back as 1994, we made over 10 million watts of fusion power at PPPL in a device that used powerful magnets to contain and control 250-million-degree fuel. Fusion research took another major leap forward in 2021 with two remarkable results. First, the National Ignition Facility at Lawrence Livermore National Laboratory achieved the first self-sustained fusion burn from a pellet ignited by the world's most powerful laser. That same year, the Joint European Torus in the UK sustained fusion conditions to release 59 megajoules of fusion energy. Dr. Luce will explain why we are confident that ITER will generate a self-sustaining reaction for long timescales.

The question therefore is not whether we can do it, but *whether we can make fusion electricity at a cost that consumers want to pay*. I am optimistic that we can, but only if we both harness the private sector to drive down cost <u>and</u> utilize the public sector – the Nation's National Labs and Universities – to propel the science and innovation forward. <u>Neither sector is sufficient alone</u>.

What should the Federal Government do now to hasten the arrival of commercial fusion and meet the administration's decadal vision that Dr. Hsu described? I will highlight some immediate actions. The National Academy of Sciences, Engineering and Medicine last year published a report <u>*Bringing Fusion to the U.S. Grid*</u>.[1] That report recommends a clear ambitious goal: *"the Department of Energy and the private sector should produce net electricity in a fusion plant in the United States in the 2035-2040 timeframe."* The first step towards this is contained in the report's second recommendation: *"The Department of Energy should move forward now*

[1] https://www.nap.edu/catalog/25991/bringing-fusion-to-the-us-grid

to foster the creation of national teams, including public-private partnerships, that will develop conceptual pilot plant designs and technology roadmaps that will lead to an engineering design of a pilot plant that will bring fusion to commercial viability." This is essential: we must urgently form these teams and develop these conceptual designs. I am delighted that the "CHIPS and Science Act" authorizes the Office of Science to: "*establish not less than 2 national teams that shall develop conceptual pilot plant designs and technology roadmaps*." We are ready to go.

My optimism about fusion's commercial prospects is not only rooted in last year's impressive results, but also in the recent step-change in our scientific understanding. Notably, advances in theory, algorithms, and high-performance computing have finally made it possible to predict the turbulence and instabilities that dominate all fusion experiments and have frustrated progress. These advances have been validated by beautiful experiments on DIII-D at General Atomics and NSTX at PPPL. Those experiments must continue as we continue to improve our predictive capability.

The solution of the fiendishly difficult turbulence problem is a triumph of the DOE-funded program. It is not just an intellectual breakthrough; it is now possible to design and optimize fusion systems *on the computer*. This is a critical advance since all fusion reactor designs require innovations to make them viable candidates for the first generation of fusion plants. With industry and university partners, PPPL is addressing the need by combining modern virtual engineering and the latest fusion science to innovate *computationally*. These powerful new tools and their potential to shorten the time to fusion electricity are also recognized in the "CHIPS and Science Act" in which the Secretary is authorized to *"establish and operate a national High-Performance Computing for Fusion Innovation Center."* This is essential.

Finally, we need to address the crucial fusion technologies that had been set aside while we mastered the containment of the hot fuel. Fortunately, the National Labs and Universities have extensive expertise that can be adapted to provide those solutions. I am thinking, for example, of the tritium capability at Savannah River National Laboratory and the nuclear technology design expertise at Idaho National Laboratory.

These are exciting times as we progress towards fusion commercialization. The number of applicants to our fusion PhD programs has nearly tripled as students sign up to help deliver the *"perfect energy source."* It will take immense private, public, and international efforts, but I am convinced we are in the end game.

Thank you again for your support, and I look forward to your questions.