Fostering a New Era of Fusion Energy Research and Technology Development
Professor Steven C Cowley, Director, Princeton Plasma Physics Laboratory

Chairwoman Johnson, Ranking Member Lucas, Subcommittee Chairman Bowman, Ranking Member Weber and committee members:

Thank you for the invitation to testify today. I am the Director of the Princeton Plasma Physics Laboratory and a professor of astrophysics at Princeton University, which manages PPPL, the lead National Laboratory for fusion 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.

Do we need fusion? The short answer is "yes." Reaching "Net Zero" by midcentury will require hundreds of gigawatts of zero carbon "firm" electricity generating capacity. That is, sources that are not dependent on sun or wind and can be switched on and off at will. As my Princeton colleague, Jesse Jenkins, emphasized at a recent PCAST hearing, a new truly sustainable firm energy source is needed.[1] Fusion is one of the very few options, and perhaps the best, to meet that need. It is therefore essential that we move to realize fusion electricity production as fast as possible.

I am more optimistic than at any time during my career that we are on the home stretch to fusion electricity. Why? The last decade has seen a huge change in our scientific understanding of fusion systems. In particular, advances in theory, algorithms and high-performance computing have finally made it possible to predict the turbulence that dominates all fusion experiments and has frustrated progress. This is a fiendishly difficult problem, and its solution is a triumph of the DOE-funded program. But it is more than an intellectual breakthrough: for the first time, it is now possible to design and optimize fusion systems *on the computer*. Current fusion reactor designs all require innovations to make them viable candidates for the first generation of fusion plants. The Princeton Plasma Physics Laboratory, with industry and university partners, is addressing the need by combining modern virtual engineering and the latest fusion science to innovate *computationally*. This modern methodology has been remarkably successful in industry – and it's a powerful new tool to shorten the time to fusion electricity.

What should we do now to hasten the arrival of fusion electricity? Dr. McCarthy will emphasize the central importance of ITER. Professor Carter will describe our community consensus plan which the leadership of this committee wisely requested. I will highlight some aspects of the plan. The National Academy of Sciences, Engineering, and Medicine earlier this year published a report *Bringing Fusion to the U.S. Grid.*[2] That report recommends a clear ambitious goal: *"the Department of Energy and the private sector should produce net electricity in a fusion plant in*

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[1] See also discussion of firm energy sources in:
https://www.sciencedirect.com/science/article/pii/S2666278721000234
[2] https://www.nap.edu/catalog/25991/bringing-fusion-to-the-us-grid

the United States in the 2035-2040 timeframe." The first step towards this goal is contained in the authors' second recommendation: *"DOE should move forward now 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 the key: we must urgently form these teams and develop these conceptual designs. It is critical, if we are to deliver fusion fast, that several conceptual designs are developed – we need to let the ideas compete. By driving design choices in a modern virtual environment, we can work backwards to determine what must be done now.

Attractive pilot plants demand high confinement. Thus, the promise of superior confinement on the National Spherical Tokamak Experiment Upgrade under construction at Princeton and the remarkably high-performance of the DIII-D tokamak at General Atomics must be cornerstones of the US program – cornerstones that will help ITER succeed and reduce the cost and scale of pilot plants.

Finally, we need to accelerate: (1) the development of materials for fusion power plants; (2) the technology for making electricity from fusion heat; and (3) the systems to breed and separate the fusion fuel tritium in the plant. These issues have been set aside while we develop the plasma confinement systems. If we are to speed fusion electricity delivery, these issues can, and should, be addressed in parallel with enhancing confinement and the design of pilot plants.

This Committee had the wisdom to authorize the activities described above in the "Energy Act of 2020" and, more recently, the "Department of Energy Science for the Future Act." We look forward to full implementation and funding for those activities which will indeed accelerate the arrival of fusion electricity.

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