Written Testimony of Prof. Stephanie Diem
Principal Investigator, Pegasus-III Experiment
Assistant Professor, Department of Nuclear Engineering and Engineering Physics
University of Wisconsin-Madison
Vice President, University Fusion Association
U.S. Science Envoy, Department of State

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Hearing on *Igniting America's Energy Future: The Promise and Progress of Fusion Power*
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Chairman Weber, Ranking Member Ross, and Members of the Committee, thank you for holding this hearing on "Igniting America's Energy Future: The Promise and Progress of Fusion Power," and for inviting me and my colleagues to testify. My name is Stephanie Diem, and I am the Principal Investigator of a large university fusion energy experiment and a professor in the Department of Nuclear Engineering and Engineering Physics at the University of Wisconsin-Madison (UW-Madison). I am also the Vice President of the University Fusion Association and a U.S. Science Envoy with the Department of State, the first science envoy appointed for fusion energy. I am speaking today as an academic researcher.

Fusion is the process that powers the sun, and is the highest power density energy source known to humankind. Fusion only happens on Earth when you have light elements at such extreme conditions – temperatures at least ten times hotter than the sun – that they combine together and release enormous amounts of energy. One of the most commonly pursued approaches relies on fusing together heavy forms of hydrogen to form helium and release energy. The energy released from fusion has the potential to provide large-scale baseload power, as well as support applications such as industrial heat, hydrogen production, space propulsion, and water desalination. Achieving fusion requires confining matter under extreme conditions, demanding ingenuity at the intersection of advanced science and engineering to both create the necessary environment and harness the resulting energy. We use innovative techniques like building magnetic bottles (magnetic confinement fusion) or focusing some of the world's largest lasers onto a target the size of a peppercorn (inertial confinement fusion) to produce conditions extreme enough to safely fuse the fuel together and release energy.

American innovation has long driven global progress in fusion energy and has brought us to this pivotal moment: the achievement of controlled fusion energy at the National Ignition Facility (NIF) in 2022, the continued emergence of transformative technological and manufacturing advances, and the establishment of public-private partnerships to develop fusion systems capable of generating electricity.[1,2] Despite the historical dominance of the U.S. in this field, we are in danger of Europe, Japan, and China outperforming the U.S. by leveraging historical U.S. innovation to advance their fusion industries. However, it is not too late to reverse the trend – history shows that when the United States invests boldly in research and innovation, it not only secures global leadership but also delivers transformative benefits to society.

Innovation Seeds Economic Development

The field of fusion energy was born out of publicly funded research, much of which occurs at universities. Universities are recognized for their ability to seed innovation that will lead to robust industries. We stand at an extraordinary juncture, as more than 45 companies across the globe are driving efforts to commercialize fusion energy. Of these fusion startup companies, 60 percent originated from universities, and 95 percent of private investment in the sector has been specifically directed to university spinouts.[3] After beginning my career at a Department of Energy (DOE) national laboratory, I returned to my home state of Wisconsin to pursue fusion energy research at UW–Madison. As an undergraduate, I had learned firsthand that experimental fusion energy thrived at UW, in part because of the historic strength of Wisconsin's manufacturing industry. University experiments focus on early stage, transformative research that seeds new companies and later evolves into partnerships during their development. The experiment that my group built was historically focused on fusion science and has expanded to focus on developing advanced technology to make fusion more economically viable. The federally funded research at UW-Madison has led to the spinout of three fusion companies, each with a different approach to fusion: SHINE Technologies, Type One Energy, and Realta Fusion, all of which have provided significant economic growth to Wisconsin and beyond.

Founded in 2010, SHINE Technologies is unique in that it has successfully commercialized fusion today. They are combatting chronic shortages of critical, lifesaving isotopes such as Mo-99 (used in medicine) by producing them domestically with neutrons generated through fusion. Still headquartered in Wisconsin, SHINE Technologies has leveraged each federal dollar invested to generate nearly four dollars in private investment. As U.S. DOE Milestone awardees, Realta Fusion (est. 2022) and Type One Energy (est. 2019) still maintain close connections with the university. Realta Fusion collaborates with UW-Madison researchers to operate a ARPA-E-funded device that leverages university infrastructure and involves partnerships with other universities, national laboratories, and private companies. As a small business, Realta Fusion has amplified federal investments (20%) by securing significant private investments (80%). Type One Energy has been able to leverage federal investments (10%) to raise significant private funds (90%). As recently as last week, Type Energy and the University of Wisconsin won a DOE Innovation Network for Fusion Energy (INFUSE) award that will support work that will benefit the entire fusion community. These UW-spinout companies are just a few examples of the many fusion energy companies that have emerged from universities across the country, serving as vehicles for amplifying federal funding to attract private investments, creating high skilled jobs for Americans, and driving economic growth. The ties between these companies and universities do not end when a company is formed and in many cases, continue to grow. Academic institutions play a vital role in developing critical tools, enabling technologies, and talent that support private-sector companies in achieving key developmental milestones.

Fusion is unquestionably one of the biggest technological advances in energy production in the past century. While this new technology requires significant further investments, the potential payoffs are even greater and increasingly within reach. Continued public–private partnerships will be essential as the industry moves closer to commercialization, and sustained federal funding remains a critical catalyst–seeding the early phases of innovation that private companies will build upon in the years ahead. A representative from the Wisconsin Economic Development Corporation indicated that five elements are essential for any emerging technology to succeed: innovation, manufacturing, capital, government support, and public support. Fusion is beginning to align these elements – through university-driven innovation, growing manufacturing partnerships, leveraged public and private capital, federal and state investment, and efforts to build public trust – but sustained coordination across all five will be critical to secure U.S. leadership.

Emerging Technologies Thrive with an Agile Workforce

The technology required to achieve fusion is extremely advanced. Nearly all major components on existing and planned fusion devices are unique and purpose-designed. For example, cryogenic superconducting magnet coils are kept near absolute zero, and must safely operate a few feet away from conditions that are ten times hotter than the sun. Precision and advanced manufacturing techniques are required for complex components, such as magnets and laser fusion targets, that are essential for improving the efficiency of fusion energy production. Federal funding has allowed us to solve incredibly difficult engineering challenges to achieve the success we have attained so far, but now we need to scale these unique, one-off solutions into an economically viable industry. Several critical technology gaps remain, including the development of materials capable of withstanding harsh fusion conditions, closing the fusion fuel cycle, and effectively harnessing fusion energy.[2,4,5] Federal support will be essential to address these challenges.

The fusion industry is growing rapidly and current academic programs are struggling to keep up with the workforce demands. The American fusion workforce faces numerous challenges, including shortages and retention issues, gaps in education and training, limited support for workforce development, a lack of fusion-enabling technology programs, and relatively low public engagement compared to other emerging technology fields. While significant, these challenges are not insurmountable. With sufficient resources, the academic community is well positioned to collaborate with its private-sector partners to overcome them. Last year, the National Science Foundation-sponsored Fusion Workforce Accelerator conference convened key public and private stakeholders to identify partnerships and programmatic opportunities aimed at transforming the fusion workforce to meet the demands of an applied fusion energy mission.[6] And just last month, Ranking Member Lofgren and Subcommittee Chair Obernolte introduced H.R.4999, the "STEM Education and Skilled Technical Workforce for Fusion Act".[7]

Investment is necessary to mobilize a national strategy to develop fusion curricula, software, and learning materials that build on existing resources to close current education gaps. As the U.S. faces continued decline in science, math, and reading scores, infusing fusion into the K-12 curriculum can also serve to bring excitement into the classroom. This has already been demonstrated to work in the quantum space. The Quantum Information Science and Technology Workforce Development National Strategic Plan, has established a large-scale coordinated effort to address similar workforce shortages.[8] As we push the boundaries of fusion experiments and start construction on even more first-of-a-kind pilot fusion plants in the United States, we will require a larger percentage of the workforce with precision manufacturing and advanced manufacturing experience. Fusion offers the potential to renew and strengthen America's traditional industrial base. Investment in the development of fusion energy supports local, regional, and statewide economic growth by revitalizing industries, creating jobs, and strengthening wages and incomes.

Projections have suggested that a significant portion of the fusion workforce will be solely dedicated to manufacturing and building fusion power plants. Workforce shortages are already evident. When my group built our experiment four years ago, Midwest-based technicians and machine shops proved indispensable. Today, about 40 percent of our team are technical staff, and as fusion advances toward commercialization, the workforce will continue to shift toward technical and engineering expertise. Although developing curricula and building partnerships with universities, national laboratories, private companies, community colleges, and trade schools will take time, federal investments are needed for apprenticeship programs immediately.

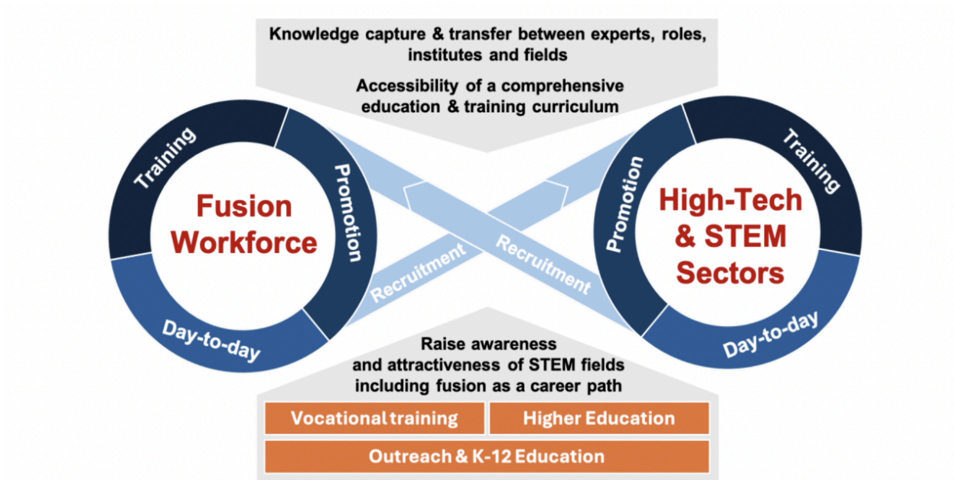

Fig. 1: Infographic detailing the interplay of the specific fusion workforce, the broader STEM workforce, and factors that improve the development and synergy of both. Figure from reference 5.

Building a Robust Fusion Ecosystem

Advancing an accelerated path to fusion energy in the United States will require a robust, integrated program–one that addresses fundamental scientific questions while driving the technical solutions needed for commercialization. The seeds of an American fusion energy ecosystem are being laid through initial funding from INFUSE and ARPA-E, targeted support for fusion pilot plant design points under the DOE Milestone program, and efforts to close critical S&T gaps through Fusion Innovation Research Engines (FIRE) Collaborations – all aimed at accelerating the economic viability of commercial fusion energy. We must act swiftly to pivot the field from its historic focus on creating the scientific conditions for fusion reactions to addressing the technical challenges of an applied fusion energy mission, while also supporting the critical growth of the fusion supply chain.[8] This transition can be achieved through federal investment in public-private regional hubs that coordinate and expand the broader fusion ecosystem, while engaging state governments to foster a supportive environment for emerging fusion companies. States such as California, Colorado, New Jersey, and Virginia are already mobilizing in the early phases of ecosystem formation. In May, Wisconsin announced the creation of the Great Lakes Fusion Energy Alliance to convene universities, national laboratories, private fusion companies, and the Midwest manufacturing industry in support of a robust fusion supply chain. Regional efforts such as these may prove transformative for states like Wisconsin, which are net energy importers and face challenges with energy supply reliability. A new baseload energy source such as fusion, combined with grid-scale storage for renewable energy, offers a robust and credible path forward.

However, ongoing uncertainty in federal fusion investments pose serious risk. Prolonged funding delays – often three to six months longer for universities than compared to funding slated for national laboratories – strain academic institutions that lack the capital to bridge funding gaps. These disruptions jeopardize workforce stability, research continuity and pace of innovation, drive talent to other sectors (or countries), and threaten the growth of private companies. At the same time, international competitors are moving ahead with coordinated national strategies and significantly expanded government support. The United Kingdom has launched a national strategy centered on building a spherical tokamak pilot plant, paired with significant funding and a coordinated workforce initiative; Germany has advanced a robust public–private partnership model; and Japan is investing heavily in new experimental facilities such as JT-60. Meanwhile, China is constructing several new fusion facilities and has made record breaking investments towards commercial fusion energy. Without a more stable federal investment framework and strategic coordinated effort,[10] the United States risks ceding leadership in fusion innovation, commercialization, and workforce development.

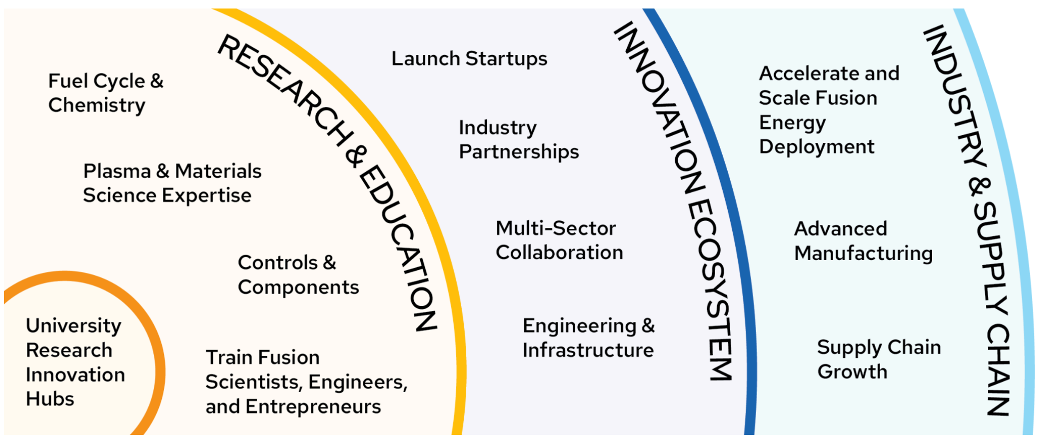

Fig. 2: Universities seed innovation that will lead to robust industries. The wide range of expertise on university campuses provides an agile framework to anticipate the needs of an emerging fusion industry.

Universities have been the engines of the fusion energy industry that has the potential to radically transform humanity's dependency and sourcing of energy. Due to the wide range of expertise on campuses, universities are flexible, nimble, and agile and this allows them to pivot and anticipate future needs of emerging technologies as they mature for deployment. For example, researchers at UW-Madison from the La Follette School of Public Affairs, the Nelson Institute for Environmental Studies, Nuclear Engineering, and Industrial & Systems Engineering are partnering to prepare a comprehensive assessment of the direct and indirect impacts of emerging fusion design concepts (life cycle assessment, environmental impacts, and byproduct materials) to support fusion energy deployment, while experts in risk communication develop strategies to build public understanding and trust. In this way, universities will continue to support and anticipate the future needs of the private fusion companies.

In a world where we are becoming increasingly concerned with how to address rapidly growing energy needs, as well as geopolitical tensions arising from access to energy and energy resources, fusion energy gives us hope. Fusion presents an extraordinary opportunity – a dense form of energy derived from hydrogen, an abundant resource, with the potential to radically transform the next phase of human progress. We have achieved remarkable scientific advances; now we need robust support to build a thriving fusion energy ecosystem. Realizing this vision will require substantial federal investments, together with highly skilled American manufacturers and technicians working alongside us to bring it to reality.

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