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Capital and R&D Support Emerging for Private Fusion Energy Development, But Questions Remain as Fusion Sector Evolves

By Barton J. Gordon, Tim L. Peckinpaugh, R. Paul Stimers, Michael L. O'Neill, and Kristen A. Berry*

Efforts in the U.S. Congress and Trump Administration, investments of private capital, and a growing cohort of fusion energy start-ups have reinvigorated interest in the long-sought goal of energy researchers and policy makers: a practical and commercially viable fusion reactor that produces net energy. The authors of this article discuss fusion energy and its future.

Nuclear fusion[1] may be an ideal energy source for the future: low carbon, plentiful and accessible fuel, and minimal safety and health risks. However, a fusion reactor that produces more energy than it consumes has remained beyond the reach of current physics and technological methods. Recognizing significant technical hurdles to constructing and operating a fusion device as part of the global energy economy, many have quipped that fusion is "thirty years away, and always will be."[2] But efforts in the U.S. Congress and Trump

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[1] As used in this analysis, "nuclear fusion" refers to the combination of two atomic nuclei into a single atom, releasing significant energy. The goal of developing a nuclear fusion reactor is to capture this energy, likely in the form of heat, and converting that energy into a usable form of energy to power modern economies. The U.S. Department of Energy provides a basic overview of the nuclear fusion process. *How Does Fusion Energy Work?*, Dep't of Energy (July 29, 2016), https://www.energy.gov/articles/how-does-fusion-energy-work.

[2] Fred Guterl, *Is Fusion in Our Future*, Scientific Am. (Mar. 1, 2017), https://www.

Administration, investments of private capital, and a growing cohort of fusion energy start-ups have reinvigorated interest in the long-sought goal of energy researchers and policy makers: a practical and commercially viable fusion reactor that produces net energy.

Congress has taken action to expand funding for fusion energy science research via the U.S. Department of Energy ("DOE"), to increase the United States' contribution to the International Thermonuclear Experimental Reactor ("ITER") project, and to direct DOE and other federal agencies to begin to investigate fusion energy more actively in order to develop future regulatory approaches. Within the Trump Administration, leaders of DOE have signaled their openness to expand support for fusion research conducted by academic institutions and commercial enterprises by pointing to examples from the nuclear fission context. In addition, 16 private fusion energy ventures have banded together to form the Fusion Industry Association ("FIA") in order to advance the efforts of the private fusion energy sector.[3] All of these developments signal that Congress, the Trump Administration, and the private sector are committed to developing a fusion energy ecosystem in the United States and around the world.

While enthusiasm for fusion development is growing and academic and private fusion efforts regularly demonstrate technological advances, many questions regarding the interplay between government and private fusion remain open. For example, which federal or state agency or agencies will regulate fusion energy activities? What regulatory philosophy will regulators use? How will regulators differentiate fusion reactors from more conventional nuclear energy systems that rely on nuclear fission reactions?[4] What should future fusion regulations cover? How can private fusion ventures access federal expertise in nuclear fusion? How might private fusion companies cooperate with federal research institutions? The answers to these questions will undergird the fusion energy industry as it begins to transition from the laboratory setting to eventually connecting with the electric power grid.

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scientificamerican.com/article/is-fusion-energy-in-our-future/.

[3] *Fusion Industry Association Announces Launch*, FUSION INDUS. ASS'N (Nov. 8, 2018), https://www.fusionindustryassociation.org/blog/fusion-industry-association-announces-launch. K&L Gates LLP provides advocacy support to FIA.

[4] In this non-technical analysis, "nuclear fission" refers to the nuclear reaction by which relatively large atomic nuclei are split, releasing energy. *Fission and Fusion: What is the Difference*, DEP'T OF ENERGY (May 7, 2018), https://www.energy.gov/ne/articles/fission-and-fusion-what-difference.

Although the private fusion community may have other near-term priorities to advance the sector,[5] this analysis focuses on current regulatory and policy considerations. By engaging with regulators and other stakeholders to answer these questions, fusion energy developers, investors, and vendors can shape the regulatory framework to promote safe operations and efficient deployment of the technology when fusion is ready to join conventional energy systems in the global energy mix.

CURRENT U.S. FUSION REGULATION

The United States has not created a comprehensive regulatory program for commercial fusion reactors. However, current federal law can be read to extend to regulate fusion energy devices. Section 11 of the Atomic Energy Act ("AEA") empowers the Nuclear Regulatory Commission ("NRC") to regulate "utilization facilities" that use "atomic energy" when those facilities' atomic energy use has "significance to the common defense and security, or in such manner as to affect the health and safety of the public."[6] Under the statute, "atomic energy" includes "all forms of energy released in the course of nuclear fission or nuclear transformation."[7] According to legislative history accompanying the 1954 amendment to the AEA, Congress may have intended the phrase "nuclear transformation" to include fusion reactions.[8] The AEA provides further that NRC may only assert its jurisdiction via a federal rulemaking procedure.

Nearly a decade ago, NRC responded to inquiries from the private fusion sector regarding the agency's approach to fusion by conducting an initial review of the state of fusion regulation. An April 2009 memorandum from NRC staff considered the question of how the federal government does, or does not, regulate fusion energy devices. The memorandum recommended that NRC assert jurisdiction over commercial fusion devices and proposed that NRC staff monitor developments in the space.[9] Furthermore, the NRC staff memoran-

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[5] FIA has stated its strategic priorities to be: (1) partnering with governments for applied fusion research; (2) driving financial support for fusion energy development, including public-private partnership models to manage risk; and (3) ensuring regulatory certainty. *Fusion Industry Association Announces Launch*, Fusion Indus. Ass'n (Nov. 8, 2018), https://www.fusionindustryassociation.org/blog/fusion-industry-association-announces-launch.

[6] 42 U.S.C. § 2014(cc).

[7] 42 U.S.C. § 2014(c).

[8] S. Rpt. No. 1699 at 11. *See also id.* at 8 (explaining that Congress changed the phrase "fissionable material" to "special nuclear material" in order to apply the provision to materials that parties use in fusion processes).

[9] R. W. Borchardt, NRC Memorandum, SECY-09-0064, https://www.nrc.gov/reading-rm/doc-collections/commission/secys/2009/secy2009-0064/2009-0064scy.pdf (Apr. 20, 2009).

dum recognized that the AEA requires that NRC conduct a rulemaking to establish jurisdiction over commercial fusion energy devices.[10]

NRC adopted its staff's recommended approach in July 2009, emphasizing that the agency "asserts, as a general matter, that the NRC has regulatory jurisdiction over commercial fusion energy devices whenever such devices are of significance to the common defense and security, or could affect the health and safety of the public."[11] But although the staff recommended "conducting further evaluations of the technical and legal issues associated with the regulation of specific fusion devices and providing more detailed recommendations to the Commission,"[12] NRC's Commissioners cautioned against expending significant resources to develop a regulatory framework for fusion until commercial deployment is "more predictable" or "much nearer at hand."[13]

Presumably because it considers commercial fusion energy to remain less predictable and not close at hand, NRC has not taken further public steps toward developing a national regulatory framework that would apply to commercial fusion energy systems or toward initiating a rulemaking to establish explicit jurisdiction over commercial fusion energy devices.

INCREASED FEDERAL INTEREST IN FUSION ENERGY

NRC may not have advanced a regulatory program for fusion energy devices, but DOE and Congress remain engaged on fusion energy research and development. DOE's Office of Science manages federal fusion research efforts, in concert with the national laboratories complex, focusing on magnetic confinement and inertial confinement fusion approaches.[14] DOE's Fusion Energy Sciences initiative also disburses funding for fusion energy research[15]

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[10] *Id.*

[11] Annette L. Vietti-Cook, NRC Memorandum on Commission Voting Record for SECY-09-0064, https://www.nrc.gov/reading-rm/doc-collections/commission/srm/2009/2009-0064srm.pdf (Jul. 16, 2009).

[12] R. W. Borchardt, NRC Memorandum, SECY-09-0064 at 1 (Apr. 20, 2009), https://www.nrc.gov/reading-rm/doc-collections/commission/secys/2009/secy2009-0064/2009-0064scy.pdf.

[13] Comments of Commissioners Dale Klein and Kristine Svinicki, NRC Voting Record, SECY-09-0064 at 5 and 7 (July 16, 2009), https://www.nrc.gov/reading-rm/doc-collections/commission/cvr/2009/2009-0064vtr.pdf.

[14] DEP'T OF ENERGY OFFICE OF SCIENCE, *Fusion Energy Sciences*, https://science.energy.gov/fes/.

[15] DEP'T OF ENERGY OFFICE OF SCIENCE, *Fusion Energy Sciences Funding Opportunities*, https://science.energy.gov/fes/funding-opportunities/.

and coordinates the efforts of the Fusion Energy Sciences Advisory Committee ("FESAC").[16]

Funding and FESAC

The U.S. Congress continues to support fusion energy research, increasing appropriations for Fiscal Year 2019 to support fusion energy science, high energy plasma, and the United States' contribution to ITER.[17] Congress also boosted support for ARPA-E,[18] which supports fusion research and development via the "ALPHA" program.[19] Finally, Congress has directed FESAC to work with DOE to "review establishing a reactor concepts research, development and deployment activity."[20]

During its meeting on December 6–7, 2018, FESAC received its new charge to review strategic plans to advance the "scientific foundation to develop a fusion energy source."[21] This assignment seeks a consensus-based strategic study on the future of burning plasma science and discovery plasma science. DOE asks FESAC to solicit input from the full fusion community, including academic and private sector contributors, via coordination with the American Physical Society's Division of Plasma Physics. Specifically, DOE requests recommendations regarding the following topics:

- Areas in fusion energy science for establishing or enhancing U.S. global leadership;
- Roles and contributions for universities, national laboratories, and industry;
- Maintaining, upgrading, or "pivoting" current fusion research facilities;
- Identifying international collaborative opportunities;
- Obtaining the maximum benefits from the ITER experiment; and
- Supporting public-private partnership ventures.

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[16] Dep't of Energy Office of Science, *Fusion Energy Sciences Advisory Committee*, https://science.energy.gov/fes/fesac/.

[17] H.R. 5895, Energy and Water Appropriations at 13, https://www.congress.gov/115/bills/hr5895/BILLS-115hr5895enr.pdf.

[18] *Id.*

[19] Advanced Research Projects Agency—Energy, ALPHA Program, https://arpa-e.energy.gov/?q=arpa-e-programs/alpha.

[20] Conference Report to Accompany H.R. 5895 at 162, https://www.congress.gov/congressional-report/115th-congress/house-report/929/1?overview=closed.

[21] Dep't of Energy, Office of Science, Letter to Dr. Donald Rej (Nov. 30, 2018), https://science.energy.gov/~/media/fes/fesac/pdf/2018/FESAC_Charge_Letter_on_Strategic_Planning.pdf.

DOE asks that FESAC consider the feasibility and technical readiness of its recommendations in light of three budgetary scenarios: maintaining current funding levels, two percent budget growth, and an "unconstrained budget." DOE explains that the unconstrained budget scenario is a place to prioritize specific activities that FESAC believes is necessary to maintain a leadership position in the scientific opportunities that the fusion community identified.

Congressional Mandates to DOE and NRC

In addition to appropriating federal funds and making a specific direction for FESAC, Congress has directed DOE to take a more active role in encouraging commercialization of advanced nuclear reactor technologies, including fusion energy. Passed by Congress and signed by President Trump on September 28, 2018, the Nuclear Energy Innovation Capabilities Act of 2017 mandates that DOE assist in the development of civilian nuclear research for eventual commercial application. The statute includes "nuclear fusion reactors" within the definition of "advanced nuclear reactors" that DOE should support.[22] According to this new law, DOE and NRC must enter into a memorandum of understanding that allows:

- DOE to gain "sufficient technical expertise to support the timely research, development, demonstration, and commercial application by the civilian nuclear industry of safe and innovative advanced nuclear reactor technology" and
- NRC to build "sufficient technical expertise to support the evaluation of applications for licenses, permits, and design certifications and other requests for regulatory approval for advanced nuclear reactors."[23]

Through this memorandum of understanding, the statute establishes the mechanism for NRC to solidify the expertise it needs to develop a regulatory framework for advanced nuclear reactors, including nuclear fusion reactors. The statute lays out an avenue for NRC to develop expertise on fusion energy and other advanced nuclear reactor technologies. The statute also directs DOE to

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[22] Nuclear Energy Innovation Capabilities Act of 2017 § 2(a), https://www.congress.gov/bill/115th-congress/senate-bill/97/text?q=%7B%22search%22%3A%5B%22s97%22%5D%7D&r=1. The statute does not define the term "nuclear fusion" or "nuclear fusion reactor," but other federal laws define "fusion" in other contexts. *See, e.g.*, Magnetic Fusion Energy Engineering Act of 1980 § 3, 42 U.S.C. § 9302(1) ("'[F]usion' means a process whereby two light nuclei, such as deuterium and tritium, collide at high velocity, forming a compound nucleus, which subsequently separates into constituents which are different from the original colliding nuclei, and which carry away the accompanying energy release").

[23] Nuclear Energy Innovation Capabilities Act of 2017 § 2(h), https://www.congress.gov/bill/115th-congress/senate-bill/97/text?q=%7B%22search%22%3A%5B%22s97%22%5D%7D&r=1.

establish a cost sharing grant program that would cover a portion of the fees associated with NRC's pre-application and application review activities.[24] Congress also requests a report within six months outlining "engineering designs for innovative fusion energy systems that have the potential to demonstrate net energy production not later than 15 years after the start of construction."[25]

Continuing this expertise building approach, Congress passed the Nuclear Energy Innovation and Modernization Act in late December 2018.[26] This measure would direct NRC to take a series of steps that may improve the licensing and permitting processes for advanced nuclear reactor projects, which the legislation defines to include "fusion" reactors,[27] including mandating the development of a "technology-inclusive regulatory framework" by 2027 that advanced nuclear reactor developers may use for their NRC licensing applications.[28] Congress also directed NRC to take a "risk-informed" approach to its licensing

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[24] Nuclear Energy Innovation Capabilities Act of 2017 § 3, https://www.congress.gov/bill/115th-congress/senate-bill/97/text?q=%7B%22search%22%3A%5B%22s97%22%5D%7D&r=1.

[25] Nuclear Energy Innovation Capabilities Act of 2017 § 2(j), https://www.congress.gov/bill/115th-congress/senate-bill/97/text?q=%7B%22search%22%3A%5B%22s97%22%5D%7D&r=1.

[26] S. 512, Nuclear Energy Innovation and Modernization Act, https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1.

[27] The legislation defines "advanced nuclear reactor" as including a "nuclear fission or fusion reactor . . . with significant improvements compared to commercial nuclear reactors under construction" as of the legislation's date of enactment. S. 512, Nuclear Energy Innovation and Modernization Act § 3 (1), https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1. Congress suggests that areas of "improvement" over current commercial nuclear reactors could include additional inherent safety features, significantly lower levelized costs of electricity, lower waste yields, greater fuel utilization, enhanced reliability, greater proliferation resistance, increased thermal efficiency, or the ability to integrate into electric and nonelectric applications. S. 512, Nuclear Energy Innovation and Modernization Act § 3 (1)(A)–(H), https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1.

[28] S. 512, Nuclear Energy Innovation and Modernization Act § 103(a)(4), https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1. The legislation defines "technology-inclusive regulatory framework" as "a regulatory framework developed using methods of evaluation that are flexible and practicable for application to a variety of reactor technologies, including, where appropriate, the use of risk-informed and performance-based techniques and other tools and methods." S. 512, Nuclear Energy Innovation and Modernization Act § 3(14), https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1.

evaluations for advanced nuclear reactors[29] and developing a program for research and test reactors.[30] Congress also directs NRC, with input from stakeholders across the nuclear sector, to develop a series of reports outlining the agency's approach to regulating advanced nuclear reactors, which likely will include the agency's approach to licensing nuclear fusion reactors.[31] And Congress also directs NRC to encourage investment in research and test reactors by authorizing the agency to issue licenses for utilization facilities that offer research and testing services, as well as energy sales.[32] President Trump signed this legislation into law on January 14, 2019.

Congress has taken further action with the Department of Energy Research and Innovation Act, also signed into law on September 28, 2018.[33] Section 307 of this new statute directs DOE to support research and development for tokamaks[34] and inertial confinement fusion energy approaches,[35] as well as "alternative and enabling concepts" that may provide "solutions to significant challenges" to achieving commercial fusion power. The statute also requires DOE to coordinate with ARPA-E and to develop a 10-year plan for fusion energy research and development activities.

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[29] S. 512, Nuclear Energy Innovation and Modernization Act § 103(a)(2), https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1.

[30] S. 512, Nuclear Energy Innovation and Modernization Act § 103(a)(3), https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1.

[31] Congress directs NRC to prepare a series of reports regarding additional stages in the licensing process for advanced nuclear reactors, the increased use of risk-informed and performance-based evaluation techniques and regulatory guidance, the research and test reactor licensing process, and regarding the technology-inclusive regulatory framework rulemaking. *See* S. 512, Nuclear Energy Innovation and Modernization Act § 103(b)–(d), https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1.

[32] S. 512, Nuclear Energy Innovation and Modernization Act § 106, https://www.congress.gov/bill/115th-congress/senate-bill/512/actions?q=%7B%22search%22%3A%5B%22s512%22%5D%7D&r=1&s=1.

[33] Department of Energy Research and Innovation Act, https://www.congress.gov/bill/115th-congress/house-bill/589/text?q=%7B%22search%22%3A%5B%22hr589%22%5D%7D&r=1.

[34] A "tokamak" is a fusion device design that uses magnetic containment. *The Tokamak* CULHAM CENTRE FOR FUSION ENERGY, http://www.ccfe.ac.uk/Tokamak.aspx.

[35] "Inertial confinement fusion" refers to devices that direct powerful lasers at small pellets of fuel, often isotopes of hydrogen, to initiate a fusion reaction. *Inertial Confinement Fusion: How to Make a Star*, LAWRENCE LIVERMORE NATIONAL LABORATORY, https://lasers.llnl.gov/science/icf.

OPPORTUNITIES TO SHAPE FUSION'S GOVERNMENT-PRIVATE SECTOR INTERFACE

Congress's mandates, the Trump Administration's efforts to accelerate commercial development of fusion technologies, and recent high-profile investments in fusion start-up companies[36] all represent opportunities to shape how the federal government interacts with private fusion energy. In addition to providing funding, Congress is seeking a path to build a fusion energy ecosystem, with full participation by the private sector. Congress has asked for input as to how it should direct its funding in the coming years, signaling its openness to suggestions for future appropriations. In addition, DOE has requested specific input regarding the development of public-private partnerships.

Several speakers during the course of the recent FESAC meeting highlighted how interested they are in developing a public-private approach and suggested that DOE's Gateway for Accelerated Innovation in Nuclear ("GAIN") program may be a good model for supporting commercial fusion efforts.[37] This public-private approach recently attracted attention in a written submission to the United Kingdom's House of Commons, signaling that other countries with maturing fusion energy sectors may follow the United States' lead to build private fusion communities in their own countries.[38]

These recent actions indicate that DOE and NRC are moving into a more active phase of involvement in the fusion energy space through the memorandum of understanding process to allow both agencies to understand the needs and goals of commercial fusion developers. The agencies' interests present opportunities for the private fusion energy sector to engage with and to shape policymakers' approaches to fusion in the years to come. As one example of this public input, the National Academy of Sciences, Engineering, and Medicine published a report on December 13, 2018, evaluating burning plasma research that highlights the importance of regulatory certainty by recommending that DOE transition its traditional oversight role over magnetic fusion activities to NRC while the fusion community begins designing a "compact" fusion pilot

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[36] Akshat Rathi, *In Search of Clean Energy, Investments in Nuclear-Fusion Startups Are Heating Up*, Quartz, https://qz.com/1402282/in-search-of-clean-energy-investments-in-nuclear-fusion-startups-are-heating-up/.

[37] *What is GAIN*, Gateway for Accelerated Innovation in Nuclear, https://gain.inl.gov/SitePages/What%20is%20GAIN.aspx.

[38] Written Evidence of Tokamak Energy Ltd., U.K. House of Commons Select Committee on Science and Technology at 5 (Oct. 2018), http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/science-and-technology-committee/technologies-for-meeting-clean-growth-emissions-reduction/written/91877.pdf?utm_source=t.co&utm_medium=referral.

plant in order to "allow for [the] commercialization of fusion power."[39] The report also encourages DOE to initiate a "national program of accompanying research and technology leading to the construction of a compact pilot plant, which produces electricity from fusion at the lowest possible capital cost."[40] And the NRC report and rulemaking processes present opportunities for the private fusion sector to differentiate itself from other parts of the advanced nuclear reactor community by highlighting differences in the fusion value chain and risk profile.

In order to take advantage of these opportunities, the fusion industry should clarify its ideal government support and regulatory environment and present these optimal conditions to policymakers for implementation. Private stakeholders should work together to solidify their policy requests to Congress and the executive agencies, clarifying what the private fusion community wants, what it does not want, and how to best implement these goals. Stakeholders in the fusion sector should take advantage of policymakers' current focus on fusion energy topics, including those policymakers' willingness to advance funding for fusion development, in order to demonstrate the value proposition of commercial fusion within the U.S. energy portfolio and to highlight U.S. leadership in this critical field of technology.

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[39] *Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research*, THE NAT'L ACAD. OF SCI., ENG'G, AND MED. at 6–13 (Dec. 13, 2018), https://www.nap.edu/catalog/25331/final-report-of-the-committee-on-a-strategic-plan-for-us-burning-plasma-research.

[40] *Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research*, THE NAT'L ACAD. OF SCI., ENG'G, AND MED. at 4–27 (Dec. 13, 2018), https://www.nap.edu/catalog/25331/final-report-of-the-committee-on-a-strategic-plan-for-us-burning-plasma-research. The report also advocates that the United States should maintain its participation in the ITER project.