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General Comment

As the Executive Director of the Fusion Industry Association, our members wanted to submit our White Paper on fusion regulation as a formal comment as the NRC considers its part 53 rulemaking. Thank you for the opportunity to comment. We look forward to engaging with you further.

Attachments

FIA Regulatory Policy WhitePaper

IGNITING THE FUSION REVOLUTION IN AMERICA

Leveraging the Lessons of the Atomic Age to Build a Regulatory Framework that Supports the Safe and Efficient Development of Fusion Energy Systems

FUSION INDUSTRY ASSOCIATION

June 2020

EXECUTIVE SUMMARY

The United States has an opportunity unlike any before. Scientific understanding and engineering developments are catching up with dreams of fusion energy's potential from the 1950s. But time is running out for the United States to establish a leading position, as many countries invest in fusion research and private companies focusing on fusion emerge around the world. Over the next 12 months, many private companies may decide where to construct their next major facilities, in the United States or elsewhere around the world. Smart, effective, and reasonable government actions now are crucial to enable the growing fusion energy industry in the United States to reach its full potential as a clean and cost-effective energy source to drive the U.S. economy in the 21st century and beyond.

The U.S. Congress, the Executive Branch, the U.S. Nuclear Regulatory Commission ("NRC"), and state regulators can all take concrete steps to enable efficient progress across this industry. Actions include maintaining the U.S. Department of Energy's ("DOE") Innovation Network for Fusion Energy ("INFUSE") program, enacting and fully funding a public-private partnership approach that Congress is considering,[1] and setting a reasonable regulatory approach for the emerging industry that balances the game-changing benefits of a healthy and sustainable fusion energy sector against the low risks associated with this advanced technology.

Policymakers, regulators, and stakeholders in the fusion energy industry need to recognize the inherent differences between the fusion energy systems that private companies, national laboratories, and universities are developing, as compared with the legacy nuclear fission facilities that make up the existing nuclear fleet in the United States and around the world. These critical distinctions demonstrate that fusion energy can be an optimal power source to underpin the energy grid of the future through production of clean, always-on power.

- Fusion power plants will have no risk of melting down and will create a minimal safety risk to the public.
- Fusion power plants' risk levels would be comparable to or lower than existing fossil fuel power plants or other industrial facilities.
- Fusion power plants planned by private developers will not use any special nuclear material or source material.
- Fusion devices will not produce any long-lived, highly radioactive waste that needs to be cooled before moving into a repository for disposition.
- Fuel for fusion is virtually inexhaustible and can be extracted from water.
- Fusion power plants will create negligible risks for proliferation.

Regulators at the state and federal levels can leverage their years of experience with atomic energy and radiological materials to implement an efficient and effective regulatory program for fusion, using standards like the NRC regulations assuring radiation protection,[2] DOE's in-depth standards for experimental fusion devices,[3] and the states' decades of regulating thermal power plants and working with the NRC to oversee handling of certain radioactive materials. This white paper outlines specific policy actions to launch fusion on a trajectory towards bringing all its security, health, safety, economic, and environmental benefits to U.S. citizens and taxpayers:

- Establish a broad regulatory and legislative framework that explicitly and permanently removes fusion energy from the same regulatory approaches that the federal government has taken towards fission power plants. Fusion is not like fission, and risk-informed evaluations of fusion can avoid unnecessary regulatory constraints. Specifically, 10 C.F.R. Parts 50, 52, in the federal regulations for fission systems or a new regulatory approach discussed for advanced fission systems (e.g., a Part 53) are not relevant to fusion systems given the radically different risk profile that an off-nominal operational event at a fusion plant presents compared to a legacy fission facility. Furthermore, only 10 C.F.R. Parts 20 and 30 governing radioactive materials and byproduct materials would apply to the commercial and demonstration fusion energy systems given the technology's minimal potential impact on the health and safety of the public. NRC Staff recently indicated that regulatory treatment of fusion energy devices could be similar to those used for particle accelerators, suggesting that Staff may agree that a different approach is needed for fusion devices as compared to the rules for existing fission reactors.

- Prepare states to take a leading role in regulating fusion energy facilities within NRC's current "Agreement State" program wherein many (39) states already play an important role in regulating radioactive sites and materials across the country. States already serve as the primary regulatory authority for conventional power generating stations around the United States. The State of Wisconsin currently has regulatory jurisdiction over the Phoenix, LLC technology that uses the deuterium-tritium fusion reaction to produce neutrons for medical treatment and industrial applications. This deuterium-tritium fusion reaction to produce neutrons is the same reaction utilized in commercial and demonstration fusion energy systems planned by many private developers. Therefore, there is existing precedent for the regulation of fusion technology by agreement states under 10 C.F.R. Part 30. Given the comparable risk profiles to conventional power stations and states' experience in overseeing the handling of certain radioactive materials, states can be ready to regulate fusion energy generating facilities under 10 C.F.R. Part 30.

- Continue the current use of risk-informed evaluations at the NRC as they determine the extent of their necessary involvement in fusion energy systems. Recognizing that fusion energy is a new technology and that the policy and regulatory requirements of the commercial fusion energy facilities will emerge as the fusion sector matures, policy makers and regulators should commit to work with industry and other stakeholders to develop a regulatory framework that will maintain progress towards creation of a safe and efficient fusion energy sector in the United States.

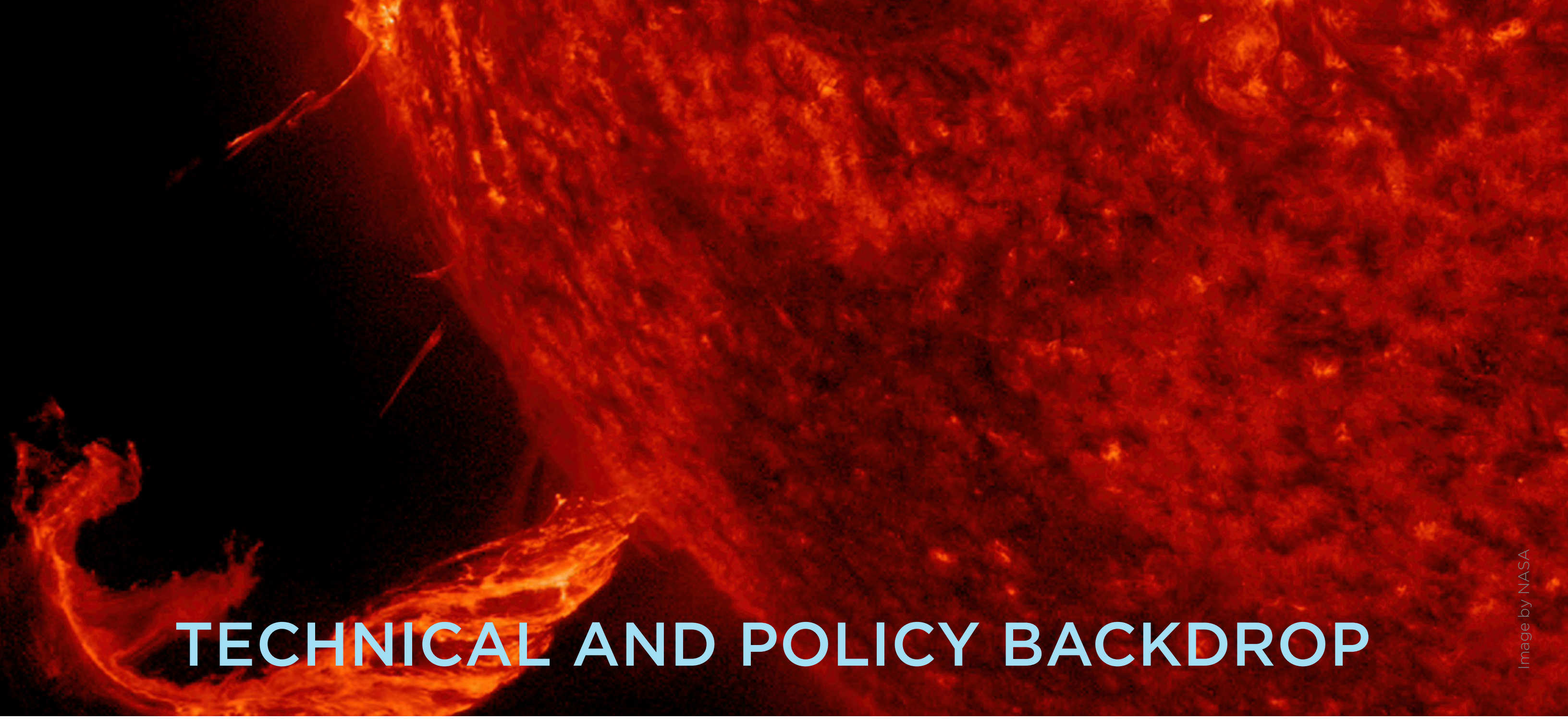


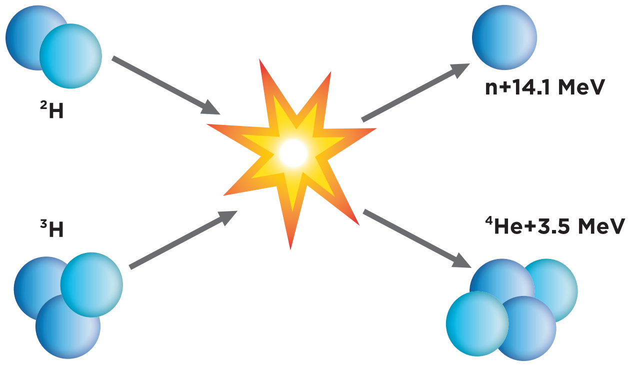
Image by NASA

TECHNICAL AND POLICY BACKDROP

What is fusion energy?

Fusion, the process by which the sun and other stars generate light, produces energy by smashing together light atoms.[4] When these light atoms are smashed together under suitable conditions, a small amount of mass is converted to an enormous amount of energy according to Einstein's famous equation $E=mc^2$. For comparison, burning one carbon atom of coal produces four electron volts worth of energy, while one fusion reaction produces over 17,600,000 electron volts worth of energy. This means that fusion is approximately 4 million times more energy dense than traditional fossil fuels.[5]

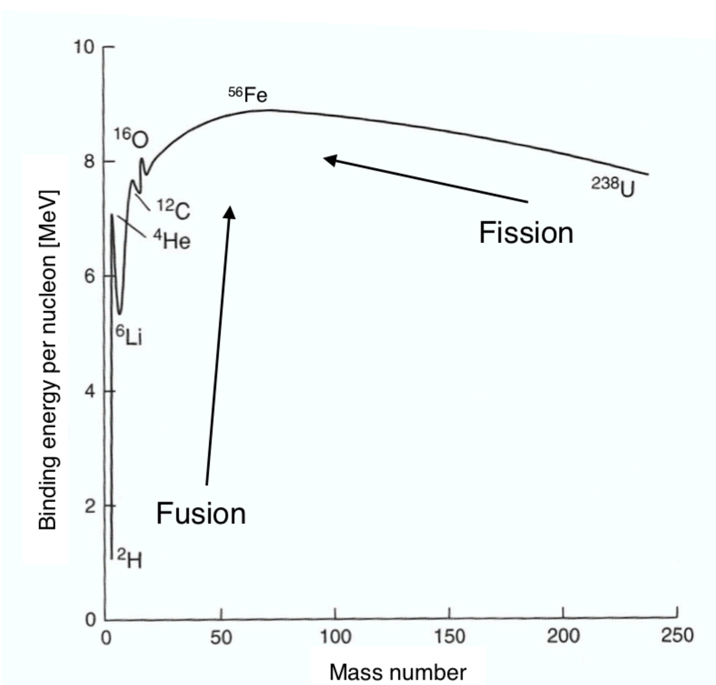
Fusion is most easily achieved on Earth by combining two isotopes of hydrogen called deuterium and tritium. Hydrogen is the lightest of all elements and is comprised of one proton and one electron. Deuterium has an extra neutron attached to the proton while tritium has two neutrons attached. In the deuterium-tritium reaction, depicted below, deuterium and tritium combine to form helium, a neutron and 17,600,000 electron volts worth of energy. Other fusion reactions, such as deuterium-deuterium and proton-boron 11, are also being studied and developed.



For fusion to occur, it's necessary to bring the two interacting nuclei so close together that the very short-range nuclear forces become stronger than the electrostatic forces that are trying to push the two positively charged nuclei apart. These conditions exist in high-density and high-temperature environments. At very high temperatures, electrons are stripped away from the nuclei to form a state of matter called plasma, which is an ionized gas. Under these conditions, the repulsive electrostatic forces that keep positively charged nuclei apart are overcome, allowing fusion of light elements to take place.

The sun uses its massive force of gravity to keep light nuclei in close enough proximity to allow fusion to occur.[6] In order to recreate conditions to induce fusion reactions on Earth, alternate strategies have to be employed, creating significant technical challenges that the fusion community is poised to solve.

By combining relatively light atoms, fusion is the opposite reaction of fission. Fission is the splitting apart of relatively heavy atomic nuclei. Both processes provide large amounts of energy that electricity generation plants can harness to power modern economies, but the crucial differences between fusion and fission are each reaction's conditions and outputs. Fusion reactions form helium, neutrons, and other stable, benign atoms. In contrast, fission reactions produce nearly the entire periodic table of elements, some of which are highly radioactive and need to be stored and cooled for long periods of time as they decay to more stable, less toxic, substances.[7] The graph below shows how the processes of fusion and fission can release enormous amounts of energy by creating more stable atoms, but approach it from opposite sides of the periodic table.



[8]

Fusion energy has potential to be the only always-available energy source that is carbon-free and does not produce long-lived radioactive waste

Like energy from fission power plants, fusion has the potential to be a source of carbon-free, always-available generation. Always available power plants constitute the backbone of the U.S. power grid by being able to meet electricity consumers' baseline demand for electricity, no matter the weather, while peaking power plants ("peaker plants" or "peakers") run intermittently to meet the electricity needs at peak, high-demand times.[9] The majority of peaker plants in the United States are natural gas-powered turbines and oil-fired units that emit airborne emissions that can exacerbate climate change. Other forms of carbon-free energy like a wind or solar power generation facility can serve as a peaker by providing an intermittent source of power if the demand coincides with times when the sun shines or the wind blows, but if this electricity commodity cannot find an immediate customer or be stored, the power could be dumped and wasted. State regulators are responsible for regulating conventional power generating stations.[10]

While fission plants can provide carbon-free, always available, generation compared to fossil fuel plant generation, fusion plants can also provide a carbon-free, always-on generation without long-lived radioactive waste, meltdown, or proliferation concerns. The waste output from a fusion facility consists of stable and benign atoms like helium plus small amounts of solid, slightly activated device components and other materials that can easily be disposed of as low-level waste. In contrast, fission facilities produce used fuel containing many highly radioactive substances that need to be stored and cooled for long periods of time as they decay to less harmful materials. Therefore, relying on fusion, rather than fission, allows the U.S. economy and energy consumers to enjoy all of the benefits of nuclear energy without any of fission's major drawbacks, including the production and storage of long-lasting high-level radioactive waste, proliferation concerns from reprocessing and enrichment facilities, and potential weaponizing of the fuel material. In fact, waste products from fusion power facilities can be disposed of at several existing low-level waste sites across the United States[11] and are not relevant to nuclear weapons.

Early regulation of atomic technologies

The U.S. government has approached nuclear innovation in fits and starts.[12] Often policymakers created the laws and governing bodies of the early nuclear fission industry to balance two fundamental dichotomies: potential risks to public safety versus the immense public utility of atomic energy. Borne out of the devastating use of fission power in World War II, the government approached the atomic era with an abundance of caution. Despite millions of hours of safe, economic, and efficient operation of the U.S. nuclear fleet over decades, a few high-profile incidents involving fission power plants, including Three Mile Island, Chernobyl, and Fukushima, have exacerbated this trepidation towards nuclear fission innovation.[13] It is critical that U.S. policymakers enabling the fusion energy industry recognize the immense inherent differences between fission and fusion energy systems and avoid unnecessary burdens on the nascent fusion industry. The action items in this analysis propose a roadmap for doing so.

The Atomic Energy Act of 1946 ("AEA") was the first law governing the use of nuclear energy in the United States.[14] The statute placed nuclear research and development solely under the jurisdiction of the federal government and created the Atomic Energy Commission ("AEC") to govern such development. The AEC held broad authority to regulate nuclear materials, including the power to shutdown nuclear-related research and development.

In 1954, Congress revised the AEA to advance private investment in the industry.[15] This statute allowed private companies to begin investing in nuclear technology and building and operating commercial reactors. Congress balanced federal and state authority over nuclear energy with the enactment of the Cooperation with States Amendment of 1959.[16] This amendment allowed the AEC (and the subsequent federal agencies regulating nuclear energy) "to enter into agreements with the Governor of any State providing for discontinuance of regulatory authority" from the AEC covering certain resources, including source materials, byproduct materials, and some special nuclear materials. When such agreements are entered, states hold "authority to regulate the materials covered by the agreement for the protection of the public health and safety from radiation hazards." However, the federal government maintains key authorities over nuclear fission activities, such as plenary authority over the design and operation of fission power stations.

The AEC retained its broad oversight of nuclear materials and atomic energy activities until the Energy Reorganization Act of 1974, which eliminated the AEC and split its main functions among two new federal agencies. The DOE governs aspects of nuclear weapons and energy development, and the NRC regulates civilian nuclear safety and public health. The NRC uses its regulations, contained in 171 different parts, including but not limited to 10 C.F.R. Parts 50 and 52 to regulate commercial scale fission reactors, 10 C.F.R. Part 20 to regulate radiation protection, and 10 C.F.R. Part 30 to regulate byproduct material. Rules like 10 C.F.R. Parts 20 and 30 provide standards for radiation protection and certain radioactive materials that would better address the risks that commercial fusion reactors might pose.

Federal efforts to address domestic fusion energy

The federal government has taken some positive steps toward encouraging the development of fusion energy in recent years in recognition of the ample benefits and minimal public safety risks of the technology, but further policy action is needed. After participants in the private fusion industry inquired about federal regulation of fusion energy, the NRC Staff issued a memorandum on April 20, 2009, to the Commissioners regarding nuclear fusion generation technology and options for its regulation.[17]

On July 16, 2009, the NRC Commissioners followed a recommendation of NRC Staff and asserted that NRC holds jurisdiction generally over nuclear fusion "whenever such devices are of significance to the common defense and security, or could affect the health and safety of the public," and concurred with its staff that the NRC must exercise its jurisdiction over private fusion activities through a rulemaking.[18] The Commissioners' approval directed NRC Staff to conduct further evaluations of the technology and legal issues for regulating nuclear fusion. The Commissioners' memorandum directed the NRC Staff to "wait until commercial deployment of fusion technology is more predictable, by way of successful testing of fusion technology, before expending significant resources."[19] The NRC has yet to issue any rulemaking asserting jurisdiction over nuclear fusion. This paper encourages the NRC to proceed as outlined in their July 2009 decision to evaluate the potential impacts of fusion energy on the "common defense and security" and "health and safety of the public."

Congress continues to consider a new public-private partnership and cost share program for fusion systems. In its appropriations legislation for Fiscal Year 2020, Congress directed DOE's Fusion Energy Sciences Advisory Committee to give full consideration to the establishment of a cost share program as part of the Committee's current long-range strategic planning process.[20] Congress further directed DOE to provide a plan to the Congressional Appropriation's Committees on a possible fusion public private partnership cost share program by June 2020, including such things as program objectives, eligibility requirements, and a funding profile. DOE has solicited input from the public regarding a potential public-private partnership program for fusion energy.[21] The Fusion Industry Association strongly supports developing such a program and looks forward to working with its membership, Congress, and DOE to implement such a program soon.

On June 7, 2019, DOE launched the INFUSE program to connect private fusion enterprises with national labs.[22] The DOE's Office of Fusion Energy Sciences supports the program with its mission of furthering the development of fusion energy through partnerships between the industry and the DOE's national laboratory complex. The program offers funding opportunities for projects with awards of $50,000 to $200,000 each and a 20 percent cost-share for private industry partners. On October 15, 2019, the DOE announced the first INFUSE awards of funding to 12 projects.[23] In its 2020 funding legislation, Congress provided $4 million to the INFUSE program and ordered DOE to open the INFUSE program to participation by U.S. domestic and international companies.[24] Separately, DOE is also seeking to fund proposals that apply quantum information science technologies and methodologies to the open questions in the fusion energy sector.[25]

The Advanced Research Projects Agency—Energy ("ARPA-E") is a federal agency within the DOE that funds research and development for state-of-the-art energy projects. To further the domestic efforts of fusion energy, ARPA-E launched the Accelerating Low-cost Plasma Heating and Assembly, or ("ALPHA,") program to fund the creation of advanced equipment critical to lowering the cost of fusion energy.[26] While the government is winding down the ALPHA program, fusion community stakeholders celebrate the program's successes and look forward to building on the ALPHA program for future public fusion funding programs. In November 2019, ARPA-E launched a successor program to ALPHA, the Breakthroughs Enabling THermonuclear-fusion Energy ("BETHE") initiative, which builds synergies with the growing private fusion industry by focusing on increasing the number and performance levels of lower-cost fusion concepts.[27] In February 2020, APRA-E announced an additional program called Galvanizing Advances in Market-aligned fusion for an Overabundance of Watts ("GAMOW") which support funding to research and develop a range of enabling technologies required for commercially attractive fusion energy.

Both the ARPA-E and INFUSE programs have been successful in promoting the fusion industry and encouraging private investment in the industry. They are important signals that the United States seeks to lead the world in fusion energy technology and deployment, but these efforts will not be successful if Congress and regulators do not combine this financial support with reasonable and efficient regulatory programs for fusion energy.

Private fusion industry's trends

Over the past few years, investment in fusion technology and research grew on a dramatic scale. Approximately two dozen companies are researching and developing fusion technology.[28] By leveraging prior publicly funded work, private investments in fusion are able to do more research and innovation at a much faster pace as compared to public-only fusion experiments.[29] Currently, the companies, universities, and national laboratories involved in fusion technologies are exploring numerous approaches to achieving viable fusion energy, including:

- Magnetic Confinement Fusion: Confining hot hydrogen plasma fuel within a chamber with magnetism;[30]
- Inertial Confinement Fusion: Compressing and heating the fuel so fast that fusion takes place prior to the central fuel interacting with surrounding materials;[31] and
- Magneto-inertial Confinement Fusion: Combining aspects of magnetic and inertial confinement to contain the hydrogen plasma fuel.[32]

Within these broad categories, the fusion industry is still evolving, with private capital emerging to support innovative ideas.

Through the Fusion Industry Association and other scientific and technical institutions in the field, the private fusion community is coalescing around several critical regulatory goals. Recognizing the differences between fusion and fission and transformational benefits that fusion offers, these groups seek consensus on key policy goals that will foster regulatory certainty, early investment capital, and a recognition of the role of fusion in building a low carbon economy. One area of broad consensus is that fusion energy systems merit a different regulatory approach than that which has been applied to fission reactors.

Image/Pixabay

WHY FUSION DEMANDS A DIFFERENT APPROACH

Fusion energy systems superficially resemble the commercial fission plants that emerged as mainstay, always-on generators in the 20th century because they both use nuclear processes (not chemical reactions like coal, natural gas, or biomass) to release thermal energy, but that is where the similarities between fusion and fission end. Critical distinctions between privately funded fusion and fission energy systems include:

- Fusion energy devices do **not** use any special nuclear or source material, creating a much lower risk profile than fission facilities, thus, criticality or meltdown accidents are physically impossible;
- Fusion creates a negligible risk of proliferation of nuclear weapons from dual-use technologies because no enrichment of fissionable materials or reprocessing to extract such materials is present;
- By employing reasonable design, construction, and operations procedures, fusion energy generating facilities would **not** create a credible safety risk to the general public (i.e., that requires an evacuation of members of the public near the fusion energy generating station) that is any greater than hydrocarbon power plants or other comparably sized industrial facilities; and
- Fusion facilities will **not** produce long-lived, highly radioactive waste.

These distinctions illustrate that fusion energy offers a dramatic advance beyond fission technology. The fusion energy industry appreciates the NRC's decision in 2009 as recognition that fusion is fundamentally different from fission and encourages all policymakers to recognize that targeted and familiar regulations, included in 10 C.F.R. Parts 20 and 30, focused on radiation protection and handling of "byproduct" material, respectively, will adequately address the limited and highly specific risks that could occur in fusion energy deployment across the U.S. energy grid.

Inputs and outputs from fusion devices present much lower risks compared to fission power stations

Congress enacted the 1954 amendments to the AEA in part to allow private industry to commercialize fission energy, but the statute also directed the AEC, now the NRC, to regulate special nuclear material, source material, and byproduct material. Fission plants use or produce these materials, but fusion facilities will not.

"Special nuclear material" includes plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235.[33] These materials are mildly radioactive and include fissile isotopes that (if concentrated) could be used as explosives in nuclear weapons.[34] No privately funded fusion energy facility will produce or utilize special nuclear material. [35]

"Source material" is material containing either the element thorium or the element uranium; provided that the uranium is not enriched in the isotope uranium-235 above that found in nature.[36] Congress described these source materials as those "essential to the production of special nuclear materials."[37] Privately funded fusion energy facilities will not use any source material.

"Byproduct material" is defined in the AEA as "any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material," waste products from processing uranium or thorium for its source material, or material that has been made radioactive by a particle accelerator for a commercial, medical, or research activity.[38] Although some externally sourced tritium may be needed to start the fusion reaction for some fusion energy systems, most privately funded fusion energy facilities will produce their own tritium on-site once the facilities are operational. Thus, the use of byproduct material will diminish over time and may end altogether as the privately funded fusion energy industry matures.

Fusion facilities will not create significant health, safety, or national security risks

Just as fusion energy facilities will not use fissile materials, there is virtually no proliferation risk from so-called "dual-use technologies," which have civilian and potential military applications.[39] As noted above, fusion facilities do not contain or require the use of special nuclear materials, nuclear enrichment facilities, or any nuclear fuel reprocessing facilities. In many cases, the fusion fuel source is deuterium, which is extracted out of water, and tritium, which can either be purchased on the private market or generated on-site.[40] Furthermore, to the extent that any of these hydrogen isotopes might be used in a nuclear weapon, their only utility is to increase the yield of a conventional nuclear weapon. By themselves, hydrogen isotopes cannot be used to create any form of a nuclear weapon.

Fusion facilities do not produce irradiated fuel that requires decay heat removal systems. If power to any fusion facility is lost (for example, during a storm that impacts the grid), if the main vacuum chamber fails, or if any other credible event occurs, then the fusion facility simply shuts down. Therefore, there is no safety reason that demands an emergency backup power system, or any other safety systems associated with nuclear fission, to protect public health and safety.

Likewise, facility design and operational procedures can mitigate the risks associated with fusion electricity generating facilities to levels comparable with existing hydrocarbon power plants or other industrial facilities.[41] No credible event at a fusion facility presents any significant risk to public health and safety, since any release of the tritium fuel offsite would be below even conservative thresholds mandating public evacuation.[42] As the American Physical Society's Division of Plasma Physics observed, the United States has "long-established expertise in safety and tritium handling."[43]

The Tokamak Fusion Test Reactor, the only U.S.-based tokamak to use tritium in its operations, was not required to have an emergency evacuation plan from any accidental release of tritium despite using a total of 30 grams of tritium over the facilities lifetime (limited to 5 grams of tritium on-site at one time). TFTR accomplished this because they were able to demonstrate that they could maintain less than the maximum acceptable total dose to the public under a worst case accident release scenario. New fusion facilities will also be able to ensure this level of protection in their designs by utilizing a variety of engineering and site-specific solutions so that the maximum dose at the site boundary is below regulatory limits for safe operation. These design solutions could include splitting up the tritium inventory in the tritium management system so that the maximum credible release is limited to what is inside the fusion reaction vessel, and several other strategies. Other industrial hazards at fusion facilities will be similar to those found in legacy fossil fuel power-generating stations and are already subject to comprehensive industrial safety oversight by federal and state authorities.[44]

Fission plants create high-level radioactive waste as used nuclear fuel from their power generating process.[45] These waste materials require long-term storage and remote handling. ***In contrast, fusion facilities do not produce highly radioactive waste that requires on-site monitoring, cooling, and eventual long-term disposal in a waste repository.*** *In addition, some fission products like gaseous iodine-131 or, like cesium-137 and strontium-90, which historically have been the isotopes of biggest concern at fission facilities, are highly soluble and readily absorbed into the biosphere and biological systems.[46] It will be physically impossible for currently envisioned fusion energy facilities to emit these types of materials, and, as noted, any tritium releases can be safely controlled with a range of options.*

The reaction products of the most common form of fusion being pursued, deuterium-tritium fusion, are helium-4 and a neutron. Other forms of fusion, including deuterium-deuterium and proton-boron-11 reactions, produce varying amounts of helium-4, helium-3, tritium, and protons. Helium and protons are not radioactive. Tritium is a beta-emitting radioactive isotope (meaning that it emits a relatively low energy electron when it decays) with a half-life of 12.3 years. In many fusion energy concepts under investigation by private and public players, tritium fuel needed to sustain the fusion reaction will be generated onsite with a blanket around the vacuum vessel comprised of lithium-6. After absorbing a neutron from the fusion reaction, this lithium blanket will produce helium-4 and tritium. Therefore, the main radioactive isotope that needs appropriate monitoring and handling procedures in a fusion energy process is tritium. The NRC currently regulates tritium as a byproduct material, meaning that the NRC's rules under 10 C.F.R. Part 30 already thoroughly address the risks associated with tritium.

Neutrons produced by the fusion reaction can activate the first wall of the vessel and/or dust inside the vessel.[47] Materials currently in use or under consideration include silicon carbide, boron carbide, graphite, carbon fiber composite, beryllium, tungsten, and lithium. These materials are either highly activation-resistant or may be activated for short periods of time. The potential hazard of an activated first wall and dust can be addressed through appropriate material selection so that activation is minimized in the first place, remote maintenance machines to minimize dose to maintenance personnel, and procedures to maintain reasonable waiting periods after operation for maintenance personnel to start work. The fusion energy community is actively researching advanced materials and other maintenance technologies to further minimize risks in this area. Furthermore, these activation products are neither gaseous nor highly soluble, minimizing risks to the biosphere and biological systems.

Additional considerations for NRC evaluation

As noted in the NRC Staff Memorandum to the Commissioners of April 20, 2009 (the "NRC Staff Memorandum"), "the Commission may be able to exercise regulatory jurisdiction over fusion devices by treating such devices as utilization facilities…" The NRC Staff Memorandum goes on to note that the AEA requires that, for treatment of a fusion facility as a utilization facility, the "Commission must find in a rulemaking both that: (1) fusion constitutes "atomic energy" within the meaning of the AEA, and (2), the fusion process is of such quantity as to be 'of significance to the common defense and security, or in such manner as to affect the health and safety of the public.'" However, commercial fusion facilities should not be utilization facilities because fusion devices will **not** be of significance to the common defense and security and their impact on health and safety of the public will fall only within 10 C.F.R. Parts 20 and 30 governing radioactive materials and byproduct materials, respectively.

Fusion processes may fall within the definition of "atomic energy" within the AEA. As noted in the NRC Staff Memorandum, atomic energy is defined to mean "all means of energy released in the course of nuclear fission or nuclear transformation." Legislative history from the time of the 1954 amendments to the AEA suggest that Congress considered "nuclear transformation" to encompass fusion reactions.[48]

In addition, Congress defined "special nuclear material" broadly enough that the AEC, or now the NRC, could include materials related to fusion energy within the definition of the term, as noted in the NRC Staff Memorandum,[50] but the NRC's own definition of special nuclear materials (updated as recently as February 19, 2019) states specifically that: "The definition [of special nuclear material] includes any other material that the Commission determines to be special nuclear material. The NRC has not declared any other material [beyond plutonium and uranium] as special nuclear material." Thus, materials usable in fusion are NOT special nuclear materials. In addition, since materials as divergent as boron, hydrogen, tritium, and deuterium are being explored for commercial use in fusion processes, the NRC would need to encompass a wide range of benign materials to determine that fusion-usable materials are "special nuclear materials."

Through this reasoning, the NRC could exercise jurisdiction over commercial fusion energy devices as "utilization facilities" under the AEA, only if such future fusion energy devices use "atomic energy in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public."[49]

- **Fusion energy facilities will *__not__* be of significance to the common defense.**[50]
  - » Commercial fusion facilities will not be capable of producing the fissionable materials that are the critical inputs for atomic weapons because there is no source material nor special nuclear material on site. Despite the fact that private fusion energy facilities do produce neutrons, using these neutrons to produce fissionable materials would be an extraordinarily challenging way to create weapons material. If desired, more detailed analysis of this possibility may be conducted, but because such creation of weapons material is an extremely complex endeavor requiring immense effort it is unlikely to be a credible threat.
  - » To the extent that fusion facilities need material particular to their activities, such as tritium fuel to start the fusion process before a plant's fuel cycle is self-sustaining, the facility operator will secure such materials on the civilian market so there is no diversion of any material resource from U.S. defense needs. Once started and sustained, fusion energy facilities will produce all the tritium fuel that they will need on-site.
  - » Once commercialized, fusion energy facilities will join an integrated electricity grid with numerous conventional thermal energy, renewable energy, fission energy, and energy storage systems as part of the nation's generation mix. It is highly unlikely that any U.S. defense facility or activity will rely solely on fusion energy for power generation in the foreseeable future.
- **Fusion energy facilities will not affect the health and safety of the public in a negative way.**
  - » All effects from abnormal operation of a fusion energy facility would be confined to the plant site and would not have a negative impact on the public, aside from potentially disrupting electric energy output from the fusion facility. As described above, fusion energy generating facilities would be constructed to comply with applicable standards for radioactive materials, including fuels like tritium, rendering residual risks from fusion energy generating facilities comparable to risks from existing hydrocarbon power plants or other industrial facilities.
  - » Fusion energy facilities will not produce high-level radioactive waste and would comply with existing rules for handling radioactive materials like tritium.
  - » In fact, by providing an emissions-free and inherently safe source of electricity, fusion energy facilities will improve the health and safety of the general public.

In 2009, NRC Staff suggested that an "additional consideration involves the potential benefits of the NRC establishing a national regulatory framework for fusion devices instead of requiring various State and local agencies to develop programs to address this new technology."[51] And States already routinely handle radioactive sources under Part 30 through the Agreement State Program (currently with 39 states participating). In the course of that program, the NRC exerts oversight over each state's programs through regular audits, so national consistency is already maintained. The success of the Agreement State Program demonstrates that these states are fully capable of exercising regulatory oversight for radioactive sources within their state, and this program is applicable to the tritium involved in future commercial fusion devices. Indeed, NRC Staff suggested that "development of requirements for fusion reactors potentially include regulatory approaches similar to those for the regulation of [particle] accelerators, which may include Agreement State considerations."[52]

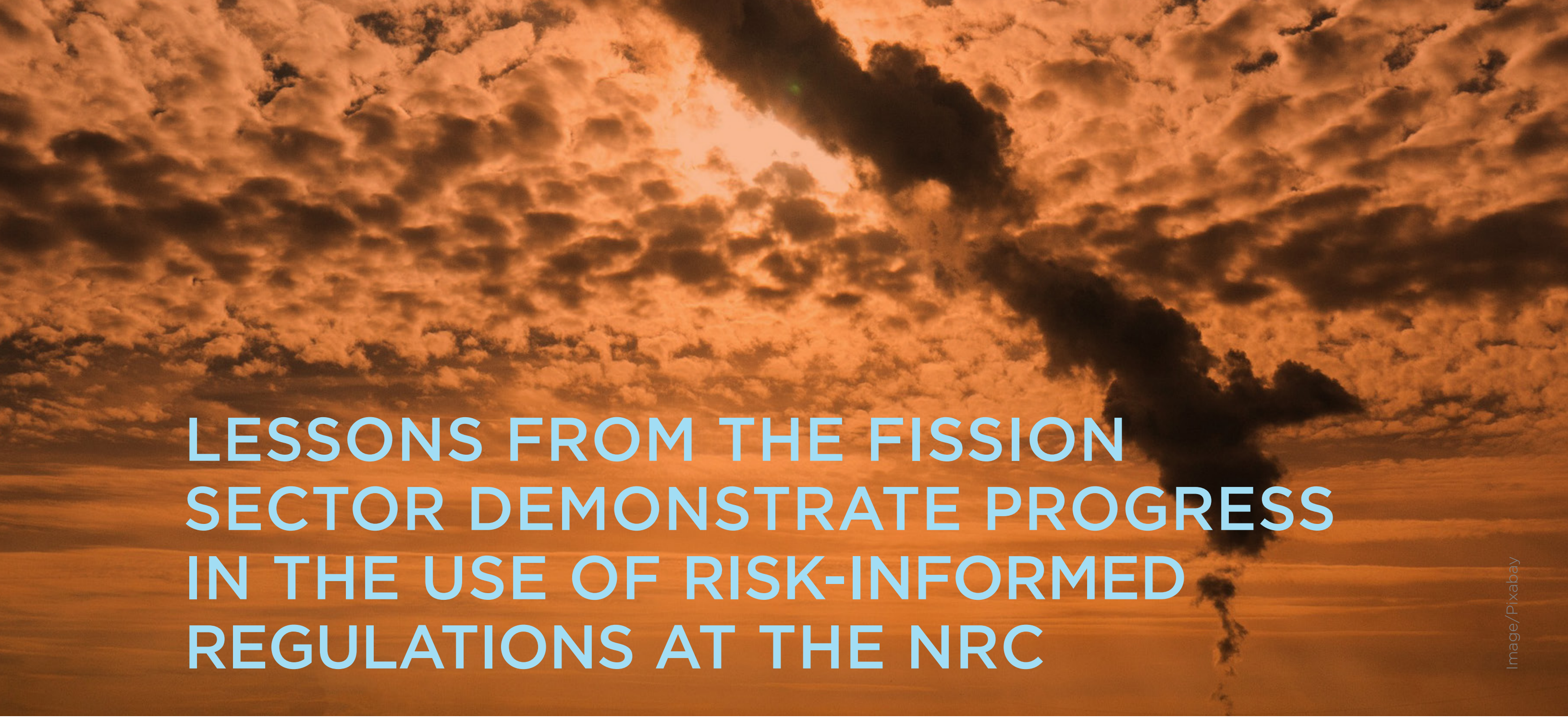
Imposing the same fission standards on the fusion sector would create a costly regulatory requirement developed to address risks that will not be present at a fusion energy facility. By comparison, France imposed its existing fully deterministic regulatory paradigms for fission facilities in order to evaluate and approve the ITER experiment. By failing to appreciate fully the significant differences between risks presented by fusion energy facilities as compared to nuclear fission plants, France's regulatory process increased ITER's construction costs and lengthened the construction timeline for the facility.

Beyond ITER, countries around the world are expanding their investments into fusion energy:

- UK government committed $248 million in October 2019 to begin design of the Spherical Tokamak for Energy Production, the first phase for moving towards a commercially viable fusion power plant by 2040.
- China has announced that it is reinvigorating its domestic fusion energy research and development program by providing $600 million worth of funding with the goal of generating electricity from a fusion energy facility around 2040.

These investments are laying the groundwork for other countries to compete with the United States for leadership in fusion energy. Other nations taking a leading role in fusion energy becomes more likely if U.S. policymakers fail to appreciate the critical differences between fusion and fission and impose the same regulatory processes that have applied to fission on fusion energy.

Given scientific and technical progress in the private fusion energy community, as well as efforts around the world to build fusion energy industries that could eclipse that of the United States, it is critical that U.S. policymakers seize this opportunity to advance the U.S. fusion energy sector.



Image/Pixabay

LESSONS FROM THE FISSION SECTOR DEMONSTRATE PROGRESS IN THE USE OF RISK-INFORMED REGULATIONS AT THE NRC

Many of the current challenges faced by the NRC involve advanced fission reactor designs that have significantly different features and risks from the large, GW-class, light water reactors now in operation in the nation. As the NRC addresses these challenges today, the agency is increasingly using risk-informed approaches to develop regulations as opposed to the prescriptive and deterministic regulations developed for the legacy reactors. The NRC now exercises risk-informed evaluations on a routine basis, and the NRC's effort to develop a rulemaking for fusion energy facilities would directly benefit from this shift to risk-informed regulation. For example, recent decisions by the NRC on the current small modular reactor application from NuScale have been driven by risk-informed studies.[53] As encouraged in the Nuclear Energy Innovation and Modernization Act (NEIMA),[54] the NRC should continue its current emphasis on risk-informed processes in developing a rulemaking for fusion energy systems.[55]

Lengthy timescales, rising costs, uncertain regulatory outcomes, and pressing competition from natural gas-fired power plants have combined to discourage investment in new nuclear fission stations in the United States. Policymakers must act to avoid condemning fusion development to a similar fate.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CURRENT ACTIVITIES RELEVANT TO DEVELOPMENT OF A RULEMAKING FOR FUSION ENERGY

Fusion energy's low-risk profile, strategic and environmental benefits, and economic potential all compel the United States to continue to invest in fusion energy and lay the groundwork for a private, civilian fusion industry that leads the world in fusion innovation and development.

The Agreement State Program already regulates a fusion facility under 10 C.F.R. Part 30

The State of Wisconsin's oversight of a deuterium-tritium fusion device offers a clear example of an agreement state's capacity to regulate fusion energy facilities under 10 C.F.R. Part 30 and may provide an important precedent for NRC rulemaking actions. As previously noted, that program allows NRC and a state to enter into an agreement where the state assumes regulatory jurisdiction over certain activities involving sources of radiation, such as source material, byproduct material, and small quantities of special nuclear material. To date, 39 states are regulating radiological materials pursuant to agreements with the NRC.[56] These agreement states monitor approximately 17,000 radioactive material licenses, which represent approximately 86 percent of all such licenses in the United States.[57] NRC oversees agreement states' regulatory programs, assuring their continued compliance with federal standards.

In 2003, NRC and Wisconsin agreed that NRC would discontinue its regulatory authority over byproduct materials, source materials, and special nuclear materials in quantities too small to form a critical mass in favor of Wisconsin state authority over these materials.[58] The Wisconsin Agreement provided that NRC would maintain jurisdiction over the construction and operation of all production or utilization facilities in Wisconsin.

Wisconsin has regulatory jurisdiction over Phoenix, LLC's neutron generators,[59] which use a deuterium-tritium fusion reaction to produce neutrons for industrial applications and medical treatment. This reaction is the same as that proposed in many commercial fusion energy facilities, using the same reactants and demanding the same level of safeguards and regulatory compliance. Recognizing that the deuterium-tritium device is not a utilization facility or a production facility, Wisconsin regulates this equipment under the agreement state program.[60]

Because fusion energy devices will be similar to the Phoenix fusion device, without any source or special nuclear materials, Congress and the NRC can look to Wisconsin's oversight of Phoenix as an example of an agreement state's expertise and capacity to regulate fusion devices under 10 C.F.R. Part 30.

DOE has already taken important steps to support the commercial fusion energy industry

Congress and the DOE have taken key steps to quicken fusion energy development by instituting the INFUSE program at DOE, ARPA-E's ALPHA, BETHE and GAMOW programs, and the Congressional mandate to NRC and DOE to begin sharing information between the agencies to build their expertise.[61]

DOE's fusion experts have already conceptualized standards for fusion energy devices at DOE facilities, captured in standards and guidance that DOE prepared initially to address an early iteration of ITER that the United States would host. Experimental fusion devices at DOE facilities in the United States have complied with DOE's requirements and standards and operated safely for years, including the DIII-D device in San Diego, the Tokamak Fusion Test Reactor and the National Spherical Tokamak Experiment at Princeton Plasma Physics Laboratory, and the Alcator C-Mod device at the Massachusetts Institute of Technology.

These standards provide additional supporting framework and best practices for regulating fusion devices, as NRC Staff suggested in 2009.[62]

- DOE-STD-6002-96:[63] Provides users with a succinct and comprehensible assembly of safety-based design and operational requirements specific to fusion facilities. Requirements were written generically so that the standard may serve as a prototype document for any agency, state or federal, that may regulate a fusion facility. These standards are intended to provide assurance that fusion energy facilities are designed, constructed, operated, modified, maintained, and removed from service in a manner that assures protection of plant workers, the public, and the environment.
- DOE-STD-6003-96:[64] Guidance for meeting the requirements identified in DOE-STD-6002-96 for an ITER-like device in the DOE environment. DOE-STD-6003-96 can serve as an example of how to implement the requirements specified in DOE-STD-6002-96 for a magnetic fusion energy facility like a tokamak magnetic confinement fusion device.
- DOE-HDBK-6004-99:[65] Handbook that provides additional documentation on good operations and design practices as well as lessons learned from the experiences of designers and operators of previous fusion facilities and related systems.
- Tritium production and handling systems: DOE-HDBK-6004-99; DOE-STD-1129-2015; and 10 C.F.R. Part 30.[66]

Ultimately, given that the risk profile of fusion energy facilities is similar to conventional hydrocarbon-fired electricity generation systems, federal and state governments should regulate fusion facilities like they regulate fossil fuel plants (with the exception of tritium and low-level activated material). This programmatic approach would recognize the intrinsic characteristics of fusion energy systems. For example, regulations for fusion would not need the same air quality standards as the Environmental Protection Agency imposes on legacy coal-fired power plants because fusion facilities' air emissions will be negligible, unlike coal facilities. As specified in DOE-STD-6002-96, regulations for fusion could use NRC guidelines for radioactive material related considerations such as 10 C.F.R. Part 20.1301 for general radiation protection procedures, and 10 C.F.R. 61 for land disposal of low-level waste.[67] Fusion facilities would also be able to comply with operational mandates for participating in the interstate power grid as established by the Federal Energy Regulatory Commission and the North American Electricity Reliability Corporation.

Congress has already directed DOE and NRC to enter into an agreement to share information on advanced nuclear systems, which the statute defines to include fusion facilities.[68] Public statements indicate that DOE and NRC have begun discussing possible approaches to commercial fusion energy devices, but further policy guidance is necessary to ensure that all potential regulators involved with fusion energy understand now is the time to assure that only regulations essential to public health and safety are developed and that any such regulations be developed through risk-informed practices.

NRC has already established precedents for regulation of fusion energy

The 2009 NRC Staff Memorandum noted that "the Commission has not exercised regulatory jurisdiction over fusion devices by developing regulations or actively participating in the licensing and/or oversight of construction or operation of existing fusion research facilities" and "various [fusion] research facilities are currently operating within the United States without NRC licensing or regulation."[69] In addition, "the NRC has been party to interagency discussions regarding ITER that have established the Department of Commerce as having jurisdiction over exports of technology and materials supporting that program. The NRC's export regulations rely on the existing definitions of 'utilization facility' and 'special nuclear material' within the NRC's regulations, which do not cover fusion devices."[70]

A NEW DAWN FOR FUSION:

Specific Actions to Enable Fusion Energy to Develop in the United States and Keep the United States Competitive in the Growing Private Fusion Sector

The NRC and Congress should adopt a regulatory and legislative framework that recognizes fusion's characteristics and potential, taking lessons learned from other emerging technologies that have advanced rapidly and have begun creating jobs and new technology for the American economy:

- **Set a Fusion-Focused Regulatory Direction.** The U.S. policymakers should establish a broad legislative and regulatory framework that explicitly and permanently removes fusion energy from the regulatory approaches that the federal government has taken towards fission power plants.
  - » The NRC's 10 C.F.R. Part 50, 52, in the federal regulations for large commercial fission systems and the new regulatory approach discussed for advanced fission systems (i.e. Part 53) address a different suite of risks compared to risks that fusion facilities could create and therefore are not appropriate for fusion systems.
  - » Rules like the NRC's Part 20 regulations for general radiation protection and the Part 30 rules for handling byproduct material would be the appropriate scope of regulation for commercial and demonstration fusion energy systems since these regulations would address fusion facilities' foreseeable risk profiles.
  - » The DOE has created a framework for safe construction and operation of experimental fusion energy devices that has worked well for decades.
- **States Take a Leading Role.** The NRC should affirm with state authorities that under 10 C.F.R Parts 20 and 30 and the "agreement state" program that States have the appropriate authority to regulate both commercial and demonstration fusion energy systems.[71] States already oversee conventional power generating stations with risk profiles comparable to future commercial fusion energy generating stations. To date, 39 U.S. states have entered into agreements to take over regulation of nuclear or radiological matters within their state borders and there is existing precedent for the regulation of fusion technology by the State of Wisconsin. This long history of state-level oversight of 10 C.F.R. Parts 20 and 30 demonstrates that state agencies have the capacity and expertise to oversee activities with similar risk profiles and technical complexity as commercial and demonstration fusion

energy facilities. Given the comparable risk profiles to conventional power stations and states' experience in overseeing the handling of certain radioactive materials, states can be ready to regulate fusion energy generating facilities under 10 C.F.R. Parts 20 and 30.

- **Federal Agencies' Coordinating Role to Develop Risk- and Performance-Based Regulations.** The NRC or other agencies should assure that any additional standards or regulations for commercial fusion energy facilities are risk- and performance-based, rather than prescriptive, which will allow industry to innovate new and improved fusion energy technologies.

These clear and reasonable steps will put the U.S. fusion energy sector on a path towards securing the health, safety, energy security and environmental benefits of this revolutionary new technology for generations to come.

ENDNOTES

[1] Joint Explanatory Statement for H.R. 1865, Rule Comm. Of the House of Representatives at 45 (Dec. 16, 2019), https://docs.house.gov/billsthisweek/20191216/BILLS-116HR1865SA-JES-DIVISION-C.pdf.

[2] 10 C.F.R. Part 30.

[3] See *infra* notes 63–65.

[4] Garry McCracken & Peter Stott, Fusion: The Energy of the Universe xvii (Elsevier Academic Press, 2005) (describing fusion as "the process in which two light atoms combine to form a heavier atom, in contrast to nuclear fission — in which a very heavy atom splits into two or more fragments" — with both processes releasing energy); *see also How Does Fusion Energy Work?*, Dep't of Energy (July 29, 2016), https://www.energy.gov/articles/how-does-fusion-energy-work (outlining the fundamentals of the nuclear fusion process).

[5] *See Nuclear Fusion Power*, World Nuclear Association (2019) https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-fusion-power.aspx.

[6] Garry McCracken & Peter Stott, Fusion: The Energy of the Universe 19 (Elsevier Academic Press, 2005).

[7] *The Fission Process*, Massachusetts Institute of Technology Nuclear Reactor Laboratory (2018) https://nrl.mit.edu/reactor/fission-process; Laila A. El-Guebaly & Lee C. Cadwallader, *Recent Developments in Safety and Environmental Aspects on Fusion Experiments and Power Plants*, in Nuclear Reactors, Nuclear Fusion & Fusion Engineering 325 (A. Aasen & P Olsson eds., 2009) (noting anticide elements include uranium, plutonium, and thorium).

[8] Public domain image from Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Binding_energy_curve_-_common_isotopes.svg

[9] *See* U.S. Gov't Accountability Off., GAO-15-652, Technology Assessment: Nuclear Reactors 4 (2015).

[10] *See, e.g.*, Mass. Gen. L. Chap. 164, § 69J1/4 (granting authority to the Massachusetts Energy Facilities Siting Board to permit power generating stations).

[11] Locations of Low-Level Waste Disposal Facilities, U.S. NRC website, https://www.nrc.gov/waste/llw-disposal/licensing/locations.html

[12] Kathleen Vaillancourt et al., *The role of nuclear energy in long-term climate scenarios: An analysis with the World-TIMES model*, 36 Energy Policy 2297 (2008).

[13] *Id. see also* Hossein P. Nourbakhsh et al., *The evolution of the U.S. nuclear regulatory process*, 102 Progress in Nuclear Energy 79–89 (2018).

[14] Atomic Energy Act of 1946, ch.724, 60 Stat. 755 (codified as amended at 42 U.S.C. §§ 2011–2297 (2006)).

[15] Atomic Energy Act of 1954, Pub. L. No. 83-703, 68 Stat. 919 (codified as amended at 42 U.S.C. §§ 2011–2297).

[16] Cooperation with States, Pub. L. No. 86-373, sec. 1, § 274, 73 Stat. 688 (1959) (codified as amended at 42 U.S.C. § 2021).

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

[18] Annette L. Vietti-Cook, Nuclear Regulatory Comm'n, *Staff Requirements – Regulation of Fusion-Based Power Generation Devices*, SECY-09-0064.

[19] *Id.*

[20] Joint Explanatory Statement for H.R. 1865, Rule Comm. Of the House of Representatives at 45 (Dec. 16, 2019), https://docs.house.gov/billsthisweek/20191216/BILLS-116HR1865SA-JES-DIVISION-C.pdf.

[21] Cost-Sharing Partnerships With the Private Sector in Fusion Energy, 85 Fed. Reg. 21,842 (Apr. 20, 2020), https://www.govinfo.gov/content/pkg/FR-2020-04-20/pdf/2020-08312.pdf.

[22] *U.S. Congress Gives Support for Private Fusion*, Fusion Industry Association (Sept. 17, 2019) https://www.fusionindustryassociation.org/post/u-s-congress-gives-support-for-private-fusion.

[23] *Department of Energy Announces Private-Public Awards to Advance Fusion Energy Technology*, News Wise (Oct. 15, 2019) https://www.newswise.com/doescience/?article_id=720776&returnurl=aHR0cHM6Ly93d3cubmV3c3dpc2UuY29tL2FydGljbGVzL2xpc3Q=.

[24] Joint Explanatory Statement for H.R. 1865, Rule Comm. of the House of Representatives at 45 (Dec. 16, 2019), https://docs.house.gov/billsthisweek/20191216/BILLS-116HR1865SA-JES-DIVISION-C.pdf.

[25] Dep't of Energy, Quantum Information Science Research for Fusion Energy Sciences, Funding Opportunity Announcement Number DE-FOA-0002225 (Apr. 20, 2020), https://science.osti.gov/-/media/grants/pdf/foas/2020/SC-FOA-0002225.pdf.

[26] *See* Alpha Program Overview, ARPA-E, https://arpa-e.energy.gov/sites/default/files/documents/files/ALPHA_ProgramOverview.pdf; Advanced Research Projects Agency – Energy, ALPHA Program, https://arpa-e.energy.gov/?q=arpa-e-programs/alpha.

[27] Breakthroughs Enabling THermonuclear-Fusion Energy, Advanced Research Projects Agency – Energy, https://arpa-e.energy.gov/?q=arpa-e-programs/bethe.

[28] Jon Asmundsson & Will Wade, *Nuclear Fusion Could Rescue the Planet from Climate Catastrophe*, Bloomberg (Sept. 28, 2019) https://www.bloomberg.com/news/features/2019-09-28/startups-take-aim-at-nuclear-fusion-energy-s-biggest-challenge.

[29] *Id.*

[30] Garry McCracken & Peter Stott, Fusion: The Energy of the Universe 41 (Elsevier Academic Press, 2005).

[31] *Id.*

[32] Gordon Long, *Prospects for Low Cost Fusion Development*, The MITRE Corporation (Nov. 2018) https://fas.org/irp/agency/dod/ja-

son/fusiondev.pdf.

33 42 U.S.C. § 2014(aa).

34 In the legislative history underpinning the AEA's definition of "special nuclear material," the Joint Committee on Atomic Energy explained that it decided to replace the term "fissionable material" with "special nuclear material" to ensure that the AEC, now the NRC, would have the power to regulate "materials which can be utilized in fusion processes." S. Rep. No. 1699 at 8–9 (1954). However, in the 65 years since Congress granted this authority to the NRC, the agency has not taken any action to expand this definition to materials that are or might be used in fusion energy experiments or facilities.

35 It is possible that the first few fusion facilities will need to purchase tritium from an outside supplier, in which case this fusion fuel could be classified as "byproduct material."

36 42 U.S.C. § 2014(z); *see also* 10 C.F.R. § 40.4.

37 S. Rep. No. 1699 at 17 (1954).

38 42 U.S.C. § 2014(e).

39 *See* 15 C.F.R. § 730.3 ("The term 'dual use' is often used to describe the types of items subject to the EAR. A "dual-use" item is one that has civil applications as well as terrorism and military or weapons of mass destruction ("WMD")-related applications.").

40 Not all fusion technologies that are under scientific and engineering evaluation use deuterium or tritium, but this fuel mixture is the most common approach among current private fusion energy developers.

41 The NRC's rules at Part 20 and 30 offer a clear set of rules that can mitigate risks from an off-site release of radioactive material like tritium or the handling of activated components from a fusion energy device.

42 A limited tritium release is the only type of scenario that could result in a radioactivity release that could have impacts beyond the fusion facility's property line. Fusion facilities will be designed and operated so that no public evacuation will be necessary, even in the event of an off-normal event.

43 Am. Physical Society, A Community Plan for Fusion Energy and Discovery Plasma Sciences 83 (2020), https://drive.google.com/open?id=1w0TKL_Jn0tKUBgUc8RC1s5fIOViH5pRK. The Fusion Industry Association's members expect to work with the broader fusion scientific and engineering community to develop a robust process for building safe and efficient fusion power plants, as suggested by the American Physical Society's report. *Id.*

44 *See, e.g.,* Occupational Safety and Health Admin., Electric Power Generation, Transmission, and Distribution Industry, https://www.osha.gov/SLTC/powergeneration/industry_hazards.html.

45 Nuclear Regulatory Comm'n, Backgrounder on Radioactive Waste, https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html.

46 For discussion of the release inventories for these materials at the Fukushima incident, see J.W. Ramsdell, Jr. et al., *RASCAL 4: Description of Models and Methods*, U.S. Nuclear Regulatory Comm'n at 1-36 (2012) https://www.nrc.gov/docs/ML1303/ML13031A448.pdf (describing the "release of radioactive material" at the accident with nuclear reactors at the Fukushima Daiichi site with "I-131 and Cs-137 activity released to the environment."). For further background on the release of these materials in the fission context, see also Tetsuji Imanaka et al., *Comparison of the accident process, radioactivity release and ground contamination between Chernobyl and Fukushima-1*, 56 J. of Radiation Research Suppl. 1, i56–i61 (2015) https://doi.org/10.1093/jrr/rrv074.

47 Jim Heirbaut, *How to Line a Thermonuclear Reactor*, Science, (Aug. 16, 2012) https://www.sciencemag.org/news/2012/08/how-line-thermonuclear-reactor.

48 S. Rep. No. 1699 at 12 ("'Atomic energy' is defined to mean 'all forms of energy released in the course of nuclear fission or nuclear transformation.' This definition includes both fission and fusion types of nuclear reactions. It has been clarified to mean only that energy released 'in the course of' nuclear fission or nuclear transformation.").

49 42 U.S.C. § 2014(cc).

50 NRC has not established a threshold impact from activities within its jurisdiction that it will deem to create common defense and security concerns. *In the Matter of Radiac Research Corp.*, 60 N.R.C. 387, 390–91 (2004). In the context of export license applications, NRC considers whether the action will be "inimical to the common defense and security" by determining if there is an "unacceptable likelihood of grave or exceptionally damage to the United States." *In the Matter of the US Dep't of Energy*, 59 N.R.C. 357, 375 (2004).

51 NRC Staff Memorandum at 4.

52 Margaret M. Doane, NRC Memorandum, SECY-20-0032 at 7 (Apr. 13, 2020), https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML19340A047.

53 *See, e.g., Safety Evaluation: Electric Power*, U.S. Nuclear Regulatory Comm'n, at 8-1 (Nov. 22, 2019), https://www.nrc.gov/docs/ML1931/ML19319A684.pdf (describing the NRC Staff's determination that the small modular reactor design that NuScale has demonstrated that no Class 1E backup power system is necessary for the safety of the facility).

54 Nuclear Energy Innovation and Modernization Act, Pub. L. 115-439, § 103(a)(4) (directing the NRC to complete a "rulemaking to establish a technology-inclusive, regulatory framework for optional use by commercial advanced nuclear reactor applicants for new reactor license applications").

55 Draft Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors, 86 Fed. Reg. 19132 (May 3, 2019).

56 U.S. Nuclear Regulatory Comm'n, NRC: NMSS - State Regulations and Legislation, https://scp.nrc.gov/rulemaking.html.

57 U.S. Nuclear Regulatory Comm'n, Frequently Asked Questions on the Agreement State Program and The Wyoming Agreement State Application, https://www.nrc.gov/about-nrc/state-tribal/agreement-states/wyoming-faq.html.

58 Agreement between the U.S. Nuclear Regulatory Comm'n and the State of Wisconsin for the Discontinuance of Certain Comm'n Regulatory Authority and Responsibility of the State Pursuant to Section 274 of the Atomic Energy Act of 1954, as Amended (June 2003), https://scp.nrc.gov/special/regs/wiagreements.pdf ("Wisconsin Agreement").

59 *Neutron Generators*, Phoenix, LLC, https://phoenixwi.com/neutron-generators/.

60 *Phoenix Nuclear Labs, LLC*, Wisc. Dep't of Health Serv., Radioactive Materials License No. 025-2034-01.

[61] Nuclear Energy Innovation Capabilities Act of 2017, Pub. L. No. 115-248, § 2(a), 132 Stat. 3,155 (2018).

[62] NRC Staff Memorandum at 6.

[63] Dep't of Energy, *Safety of Magnetic Fusion Facilities: Requirements*, (May 1996) https://www.standards.doe.gov/standards-documents/6000/6002-astd-1996/@@images/file.

[64] Dep't of Energy, *Safety of Magnetic Fusion Facilities: Guidance*, https://www.standards.doe.gov/standards-documents/6000/6003-astd-1996/@@images/file (May 1996).

[65] Dep't of Energy, *Supplementary Guidance and Design Experience for the Fusion Safety Standards*, https://www.standards.doe.gov/standards-documents/6000/6004-bhdbk-1999/@@images/file (Jan. 1999).

[66] In addition to these fusion-focused safety materials, policymakers could also draw some technical and safety standards from NRC's legacy radiological standards, including general radiation protection procedures and low-level waste disposal at 10 C.F.R. Part 20 and portions of 10 C.F.R. Part 30 for site decommissioning plans.

[67] Given the results of some analyses of coal power plants' emissions, perhaps coal plants should be subject to radioactive emissions standards as well. See, e.g., Mara Hvistendahl, *Coal Ash is More Radioactive than Nuclear Waste*, Scientific Am. (Dec. 13, 2007) ("[C]oal ash released from a power plant delivers more radiation than nuclear waste shielded via water or dry cask storage.").

[68] Nuclear Energy Innovation Capabilities Act of 2017, 42 U.S.C. § 16278(e). The agencies implemented this congressional directive in October 2019. Memorandum of Understanding between U.S. Dep't of Energy and U.S. Nuclear Regulatory Comm'n on Nuclear Energy Innovation (Oct. 7, 2019), https://www.energy.gov/sites/prod/files/2019/10/f67/MOU%20DOE-NRC%20Nuclear%20Energy%20Innovation.pdf.

[69] NRC Staff Memorandum at 4.

[70] NRC Staff Memorandum at 5.

[71] 42 U.S.C. § 2021(b).

FUSION INDUSTRY ASSOCIATION

The Fusion Industry Association is an international coalition of companies working to electrify the world with fusion — the unparalleled power of the stars. Energy from fusion will provide clean power for everyone that's safe, affordable, and limitless.

The Fusion Industry Association is a registered non-profit organization composed of private companies working to commercialize fusion power. The Association advocates for policies that would accelerate the race to fusion energy.

fusionindustryassociation.org