Considerations in the Regulation of Fusion-Based Power Generation Devices

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With advances in technology, the long sought-after development of fusion power, which promises a limitless, carbon-free source of energy for the future, finally appears within reach. Over two-dozen private companies are developing fusion technology,[1] supported by both private and public funding.[2]

The U.S. Nuclear Regulatory Commission (NRC) has recently instructed its Staff to develop options for Commission consideration on the licensing and regulation of fusion energy systems,[3] and NRC Chairman Kristine Svinicki has remarked at a recent public forum that "I don't think there's any lack of a statutory provision that stops us today from continuing to move forward" with the development and licensing of fusion technologies.[4] The Department of Energy's (DOE) Under Secretary for Science, Paul Dabbar, similarly remarked at that forum that DOE has not so far identified any specific need to get enabling legislation to facilitate the licensing and regulation of fusion.[5]

While the development of an appropriate regulatory framework for fusion energy is important, and commenters appear to accept that the NRC may assert regulatory jurisdiction over fusion energy under the Atomic Energy Act,[6] insufficient attention has been given to date to the implications of regulating fusion energy under the Atomic Energy Act in its current form. As discussed below, the NRC's ability to regulate fusion energy is largely predicated on the NRC's ability to define fusion devices as "utilization facilities" under the Atomic Energy Act, but there are some significant issues that would be raised by doing so.

The NRC's ability to exercise regulatory jurisdiction over fusion devices was analyzed by the NRC Staff in 2009.[7] As the NRC Staff explained, the NRC may exercise jurisdiction over fusion energy devices by licensing and regulating them as "utilization facilities" under the applicable provisions of the Atomic Energy Act.[8] The NRC Staff parsed Section 11 of the Atomic Energy Act as defining a utilization facility as "any equipment or device ... determined by rule of the Commission to be capable of making use of ... 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."[9] "Atomic energy" is defined in the Atomic Energy Act to mean "all forms of energy released in the course of nuclear fission or nuclear transformation,"[10] and the NRC Staff identified legislative history indicating that this definition includes fusion reactions.[11]

The NRC Commissioners approved the NRC Staff's recommended assertion of 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.[12] The Commission also instructed the NRC Staff to "conduct further evaluations of the technical and legal issues associated with the regulation of specific

fusion devices and provide status information regarding the development of fusion technology in the quarterly updates on the status of new reactor licensing activities."[13] Unfortunately, sufficient evaluation of the legal issues has not yet occurred.

There are a number of legal issues with adverse ramifications that will arise if the NRC proceeds in establishing a regulatory framework for fusion energy predicated on defining a fusion energy device as a utilization facility. Examples are discussed below:

First, a utilization facility, which would be licensed under Section 103 of the Atomic Energy Act, is subject to the provisions of the Price Anderson Act (Section 170 of the Atomic Energy Act, 42 U.S.C. § 2210) requiring it to maintain financial protection to cover claims for nuclear incidents. In particular, any such facility designed to produce substantial amounts of electricity and having a rated capacity of 100,000 electrical kilowatts or more would be required not only to maintain the maximum amount of primary financial protection available at reasonable cost and on reasonable terms from private sources (such as insurance), but also to maintain secondary financial protection under an industry retrospective rating plan under which each licensee could be assessed a deferred premium up to $95.8 million adjusted from 2005 for inflation[14] to cover the liability for a nuclear incident at its own utilization facility or another's if the primary financial protection is exceeded.[15] Consequently, licensing a fusion energy device as a utilization facility would appear to make each such facility liable for some portion of the liability if a serious nuclear accident were to occur at a U.S. fission reactor, if that liability exceeded the reactor's primary financial protection. That alone might deter any U.S. company from seeking a license to operate a fusion facility.[16]

Second, licensing a fusion energy device as a utilization facility would preclude the facility owner or operator from being owned, controlled, or dominated by an alien, a foreign corporation, or a foreign government.[17] This would unnecessarily hinder partnering with a foreign entity, or the development of fusion power by U.S. utilities that have foreign parents.[18]

Third, treating a fusion energy device as a utilization facility would impose the licensing process applicable to fission reactors, requiring a construction permit before a facility could be built, an operating license before it could be operated, and a mandatory hearing in any construction permit proceeding.[19] While the Atomic Energy Act allows issuance of a combined construction permit and operating license, that procedure still requires a mandatory hearing, and provides for an additional hearing opportunity before operation regarding whether inspections, tests, analyses, and acceptance criteria specified in the combined license have been met.[20] Further, subsequent amendments to a license for a utilization facility would generally require 30-days prior notice in the Federal Register (unlike amendments to materials licenses) and would require a prior hearing absent a finding that the amendment involves no significant hazards consideration.[21] If the hazards of operating a fusion facility are substantially less than those raised by fission reactors, freighting fusion facilities with these types of procedures would be unnecessary and unfortunate.[22] Further, when the NRC begins regulating fusion energy devices, a requirement for construction permits could significantly disrupt ongoing research and development projects.

Fourth, the individuals operating utilization facilities must be licensed, in addition to the facility operator.[23] It is unclear why there would be any need for licensed individuals at a fusion energy facility. And the facility license would be required to include technical specifications,[24] imposing a degree of prescriptiveness that may be unwarranted by the hazards of operation.

Fifth, the construction and operation of utilization facilities are licensed exclusively by the NRC, and this regulatory authority may not be assumed by a State.[25] This would preclude the State involvement that has been suggested by industry and other commenters.[26]

Sixth, defining a fusion energy device as a utilization facility would subject the device to export licensing requirements that might significantly impair the ability of U.S. companies to commercialize their technology overseas. In particular, an export of a fusion device (not currently regulated by the NRC) would become subject to NRC licensing,[27] including the inter-governmental consultation process established by Section 126 of the Atomic Energy Act,[28] and subject to the restrictions in Sections 127 – 129 of the Act.[29] For example, under Section 127 of the Act, IAEA safeguards as required by Article III(2) of the Treaty on the Non-Proliferation of Nuclear Weapons are to be applied to a utilization facility proposed to be exported.[30]

The issues discussed above are not exhaustive. There are likely other concerns that would arise by defining a fusion device as a utilization facility.

It has been suggested that fusion facilities should be regulated under the NRC regulations in 10 C.F.R. Part 30,[31] which governs byproduct material over which the NRC has jurisdiction pursuant to Section 81 of the Atomic Energy Act. This would avoid the problems created by defining a fusion device as a utilization facility but appears problematic under the current definitions of byproduct material in the Act. The definition of byproduct material in the Atomic Energy Act includes "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"[32] and "any material that—(i) has been made radioactive by use of a particle accelerator and (ii) is produced, extracted, or converted after extraction ... for use for a commercial, medical, or research activity."[33] Neither of these definitions would provide a solid basis for regulating fusion energy devices.

While tritium used as fuel in a fusion device may be initially produced in a fission reactor and therefore constitute byproduct material (i.e., as radioactive material yielded incident to utilizing special nuclear material in the reactor), that may no longer be the case as fusion plants continue to operate. As they operate, fusion plants will likely be designed to breed their own tritium supply, as neutrons escaping from the plasma bombard lithium in the blanket wall. This tritium would no longer constitute byproduct material, as it would not be produced utilizing special nuclear material. In addition, some fusion devices may not use tritium as a fuel, instead relying on other reactions not involving radionuclides, such as fusing two deuterium nuclei, or deuterium with a helium nuclei.

In SECY-09-0064, the NRC Staff identified the possibility of categorizing fusion energy devices as particle accelerators.[34] If a fusion energy device were considered to be a particle accelerator, perhaps tritium being bred during operation of the facility would constitute byproduct material. The NRC Staff, however, determined that "additional evaluations are needed to assess whether specific fusion energy devices could be reasonably categorized as accelerators and if the resultant radioactive materials are produced for a commercial, medical or research activity."[35] Such an evaluation has not been performed, and it is questionable whether the radioactive materials produced in a fusion energy device could be classified as accelerator-produced byproduct material. A fusion energy device would not normally be considered a particle accelerator as that term is commonly understood, and there is no indication that Congress intended the reference to a particle accelerator to extend to a fusion energy device. Perhaps one might argue that a magnetic-confinement fusion device meets the NRC's definition of a particle accelerator, which is "any machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 megaelectron volt."[36] But while one might argue that charged particles in the plasma in a magnetic-confinement fusion device are being accelerated, the neutron radiation discharged from the device into tritium breeding blankets does not result from accelerating the particles but from the fusion reaction. Further, while classifying a fusion energy device as a particle accelerator might allow the NRC to regulate tritium being bred and extracted as byproduct material (as radioactive material produced or extracted for commercial use), it would not provide a basis for the NRC to regulate fusion energy devices not fueled with or breeding tritium.[37] In sum, while perhaps some devices could be shoehorned into the NRC's definition, any such interpretation would reach only certain designs and would be very vulnerable to a challenge on judicial review.

Alternatively, the NRC might regulate fusion by defining the fuel as special nuclear material, over which it has jurisdiction pursuant to Section 51 of the Atomic Energy Act.[38] That Section authorizes the Commission, with Presidential assent, to define material as special nuclear material upon a finding that "such material is capable of releasing substantial quantities of atomic energy" and that "the determination that such material is special nuclear material is in the interest of the common defense and security."[39] If the fusion fuel stock were defined as special nuclear material, the activated structures and materials produced during operation would then constitute byproduct material (material made radioactive by radiation incident to the use of special nuclear material). But this approach would have several substantial drawbacks. Foremost, it seems highly unlikely that the NRC could define fusion fuel materials as special nuclear material without defining the fusion device as a utilization facility, as these definitions are intertwined.

Further, this approach might require licensing of material such as deuterium that is not radioactive and has other applications. In addition, if the fusion facility were producing tritium defined as special nuclear material, it would also become a "production facility" subject to much of the same requirements under the Atomic Energy Act as those applicable to a utilization facility; and fission reactors producing tritium in significant quantity might also become production facilities. Moreover, export of fusion energy technology could potentially become controlled under Section 57(b) of the Atomic Energy Act, which prohibits any person from directly or indirectly participating in the development or production of special nuclear material outside of the United States except as authorized by a 123 Agreement and specific authorization in a subsequent arrangement, or upon authorization by the Department of Energy (pursuant to 10 C.F.R. Part 810). This would not only complicate the employment of any non-U.S. citizens or green-card holders in any U.S. fusion company (to avoid a "deemed export") but also result in unnecessary restrictions on export of a technology with no proliferation concerns.

In short, regulating fusion power under the Atomic Energy Act raises a host of issues that deserve careful consideration by the NRC and may well necessitate amendments to the Atomic Energy Act. Legislation amending the Atomic Energy Act would provide certainty regarding the NRC's authority and allow the NRC to establish a uniform regulatory framework. If the NRC lacks jurisdiction, the regulation of fusion facilities would be left to the States, which could lead to disparate regulatory requirements.

Perhaps the cleanest approach, and the one that would provide the most regulatory certainty, would be to amend the Atomic Energy Act to: (1) add a new Section requiring a license for a fusion energy facility, similar to the provision requiring licensing of materials and without invoking the many restrictions and procedures applicable to utilization facilities; and (2) revise the definition of byproduct material to include material made radioactive in a fusion energy device. A new provision requiring licensing of a fusion energy facility under the Atomic Energy Act would allow the NRC to regulate the facility (including any radioactive material used as a fuel source) without defining it as a utilization facility, and would allow the NRC to discontinue its regulatory authority to permit State regulation under Section 234 of the Atomic Energy Act upon an NRC determination that the State has established regulations sufficiently compatible with the federal regulatory framework.

The NRC and Congress should also consider whether the Nuclear Energy Innovation and Modernization Act (NEIMA)[40] should be amended, as NEIMA may have inadvertently reinforced a view that fusion energy devices should be regulated as utilization facilities. Although NEIMA contains no provision directing that a fusion facility be regulated as a utilization facility, it conflates fission and fusion reactors in its definition of an "advanced nuclear reactor;"[41] and as a result, its direction to the Commission to establish a technology-inclusive regulatory framework for advanced reactors[42] might be interpreted as implying that both types of facility should be regulated in the same manner.[43]

It should be noted that it is not necessary to treat a fusion device as a utilization facility in order to ensure a safety review commensurate with applicable hazards. If the NRC's jurisdiction to regulate a fusion energy facility as a materials licensee is established, the NRC would still have the ability to require an integrated safety analysis similar in concept to that applied to fuel cycle facilities as part of a regulatory framework for fusion devices, if warranted, and should consider this approach in establishing that framework.[44] But just as the Atomic Energy Commission did when fission reactors were first being developed, the NRC should initially establish a framework that is inherently flexible to accommodate developing designs and that imposes the minimum amount of regulations as will permit the Commission to fulfill its obligations under the Atomic Energy Act. Further, any rulemaking establishing licensing requirements for fusion facilities needs to address the impact of new regulations on research and testing projects underway, so that such projects do not become immediately in violation of the new regulations (as might occur if construction permits were suddenly required) or deterred from continuing their development activities.

In sum, the United States is on the verge of achieving fusion energy, and it is time to determine how fusion energy facilities will be regulated, so that companies developing the technology understand what will be required and development activities are not overly burdened or interrupted. Regulation by the NRC under

the Atomic Energy Act is sensible to achieve a uniform, nationwide regulatory framework and apply the NRC's expertise. But that framework should avoid the over-regulation that would occur if fusion energy facilities are treated as utilization facilities and regulated like fission reactors. Instead, the NRC and Congress should consider legislation to allow such facilities to be regulated by the NRC as a separate class of facility, with the instruction to impose the minimum amount of regulations as will permit the Commission to fulfill its obligations under the Atomic Energy Act. ■

Endnotes

1 Jon Asmundsson & Will Wade, "**Nuclear Fusion Could Rescue the Planet from Climate Catastrophe**," Bloomberg (Sept. 28, 2019).

2 See, e.g., **Commonwealth Fusion Systems Raises $115 Million and Closes Series A Round to Commercialize Fusion Energy**, (June 27, 2019).

3 Memorandum from A. Vietti-Cook, Secretary, to M. Doane, Executive Director for Operations, "Staff Requirements – SECY-20-0032 – Rulemaking Plan on 'Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (RIN-3150-AK31; NRC-2019-0062)'" (Oct. 2, 2020) (ADAMS Accession No. **ML20276A293**).

4 Inside NRC, "NRC must prepare to license and regulate fusion: industry officials" (Oct. 26, 2020) at 1.

5 *Id*. at 7.

6 The Atomic Energy Act of 1954, as amended, 42 U.S.C. §§ 2011 *et seq.*

7 SECY-09-0064, Memorandum from R. Borchardt, Executive Director for Operations, to the Commissioners, "Regulation of Fusion-Based Power Generation Devices" (Apr. 20, 2009) ("SECY-09-0064") (ADAMS Accession No. **ML092230171**).

8 *Id*. at 3.

9 *Id*. In full, Section 11 of the Atomic Energy Act defines a utilization facility as meaning:

> (1) any equipment or device, except an atomic weapon, determined by rule of the Commission to be capable of making use of special nuclear material 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, or peculiarly adapted for making use of 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; or (2) any important component part especially designed for such equipment or device as determined by the Commission.

42 U.S.C. § 2014(cc). The NRC Staff's reading of this definition, as set forth in SECY-09-0064, would allow the NRC to define a fusion energy device as a utilization facility based on its making use of atomic energy, and does not appear to depend on its capability to make use of "special nuclear material." The NRC could also assert jurisdiction over a fusion device as a utilization facility by defining its fuel as "special nuclear material" under Section 51 of the Atomic Energy Act (42 U.S.C. § 2071), but such a determination would require Presidential assent and submission to the Senate Committee on Energy and Natural Resources and the House Committee on Energy and Commerce (*id*.).

10 42 U.S.C. § 2014(c).

11 SECY-09-0064 at 3, citing Report of the Joint Committee on Atomic Energy, "Amending the Atomic Energy Act of 1946, as amended, and for Other Purposes," S. Rep. No. 1699, 83d Cong., 2d Sess., June 30, 1954, at 11 ("'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.").

12 Memorandum from A. Vietti-Cook, Secretary, to R. Borchardt, Executive Director for Operations. "Staff Requirements – SECY-09-0064 – Regulations of Fusion-Based Power Generation Devices" (July 16, 2009) (ADAMS Accession No. **ML092230198**).

13 *Id.* In addition, the Commission instructed the NRC Staff, however, to wait "until commercial deployment of fusion technology is more predictable, by way of successful testing of a fusion technology, before expending significant resources to develop a regulatory framework for fusion technology." *Id*.

14 The maximum deferred premium currently adjusted for inflation is approximately $131 million. 10 C.F.R. § 140.11(a)(4).

15 42 U.S.C. § 2210(b)(1).

16 Because the provisions of the Price Anderson Act are statutory requirements, the Commission would not have the authority to exempt a licensee from the requirements. Perhaps the Commission could interpret Price Anderson as allowing it to establish different secondary coverage requirements for a different classes of utilization facility, but such an approach could be challenged on judicial review.

17 42 U.S.C. § 2133(d) ("No license [required under Section 101 of the Atomic Energy Act to receive, manufacture, produce, transfer, acquire, possess, import, or export a utilization facility] may be issued to an alien or any corporation or other entity if the Commission knows or has reason to believe it is owned, controlled, or dominated by an alien, a foreign corporation, or a foreign government.").

18 If a fusion facility were regulated under a materials license or on some basis other than as a utilization facility, the NRC would still be capable under the Atomic Energy Act of denying a license application involving foreign involvement found inimical to the common defense and security.

19 42 U.S.C. §§ 2235(a), 2239(a)(1)(A).

20 42 U.S.C. §§ 2235(b), 2239(a)(1)(B). Additional notice and review procedures apply to utilization facilities. *See, e.g.,* 42 U.S.C. §§ 2232(b)-(c). While review by the Advisory Committee on Reactor Safeguards, required by Section 182(b) (42 U.S.C. § 2233(b)) for any construction permit or operating license for a utilization facility, would seem desirable for fusion energy facilities during early development, there may not be any need for such reviews once the technology has matured.

21 42 U.S.C. §§ 2239(a)(1)(A), 2239(a)(2).

22 In contrast, the Atomic Energy Act does not require construction permits, or prior notices or prior hearings, for the issuance or amendment of materials licenses.

23 42 U.S.C. § 2137.

24 42 U.S.C. § 2232(a).

25 42 U.S.C. § 2021(c)(1).

26 The Fusion Energy Association, ***Igniting the Fusion Revolution in America*** at 20-21 (June 2020); A. Roma and S. Desai, ***The Regulation of Fusion – A Practical and Innovation-Friendly Approach*** (Feb. 2020) at 9.

27 42 U.S.C. § 2131.

28 42 U.S.C. § 2155.

29 42 U.S.C. §§ 2156-2158.

30 42 U.S.C. § 2156(1). The wording of Section 127(1) is unfortunate, because III(2) of the Treaty on the Non-Proliferation of Nuclear Weapons would not impose IAEA safeguards on equipment unless designed for the processing, use or production of special fissionable material.

31 *Igniting the Fusion Revolution in America, supra* note 26, at 20; *The Regulation of Fusion, supra* note 26, at 14.

32 42 U.S.C. § 2014(e)(1).

33 42 U.S.C. § 2014(e)(3)(B). There are other types of byproduct material as defined by the Atomic Energy Act, but they would have no applicability to a fusion energy device.

34 SECY-09-0064 at 4.

35 *Id.*

36 10 C.F.R. § 30.4.

37 Treating a fusion energy device as a particle accelerator would also not allow the NRC to regulate the possession and use of the fusion energy device itself. See Requirements for Expanded Definition of Byproduct Material, Final Rule, 72 Fed. Reg. 55,864, 55,868 (Oct. 1, 2007) ("The [Energy Policy Act of 2005, which extended the definition of byproduct material to encompass certain accelerator-produced radioactive material] does not give the NRC authority to regulate the possession or use of particle accelerators."). This could result in concurrent NRC and State regulation, with NRC regulating the possession of byproduct material and States regulating the possession and use (e.g., design and operation) of the fusion energy device.

Further, it is questionable whether treating a fusion energy device as a particle accelerator would allow the NRC to regulate as byproduct material the other radioactive materials and structures that become activated by neutron bombardment, as these radioactive materials would not be produced and extracted for commercial use. While the NRC might seek to regulate these activated materials as incidental to the production of tritium, similar to its regulation of activation products in accelerators (*see id.*), such an assertion of jurisdiction might be challenged since the activation of structures and other materials would be predominantly incidental to fusion, and not to the breeding of tritium. In any event, treating a fusion-energy device as a particle accelerator would provide no basis for NRC to regulate the radioactive materials activated in fusion-energy devices that are not fueled with tritium.

38 42 U.S.C. § 2071.

39 *Id.* As the NRC Staff observed in its 2009 analysis, the term "special nuclear material" was used in the Atomic Energy Act "to give to the Commission, in addition to the power to determine and regulate the use of materials utilizable in the fission process, the power to perform the same function in respect to materials which can be utilized in fusion processes." SECY-09-0064 at 3, quoting S. Rep. No. 1699, *supra* note 11, at 8.

40 Pub. Law 115-439, 123 Stat. 5565 (Jan. 14, 2019).

41 NEIMA, § 3(1), 42 U.S.C. § 2215 note ("The term 'advanced nuclear reactor' means a nuclear fission or nuclear fusion reactor.").

42 NEIMA, § 103(a)(4), 42 U.S.C. § 2133 note.

43 Such an interpretation is certainly not compelled, nor does it appear to be the view of the Commission. The Commission's instruction to its Staff to develop options for Commission consideration on the licensing and regulation of fusion energy systems originated from Commissioner Hanson, who specifically stated that he "would like the staff to consider existing frameworks, such as the regulatory structure in Parts 20 and 30." Commissioner Hanson's Comments on SECY-20-0032: Rulemaking Plan on "Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (RIN-3150-AK31; NRC-2019-0062)" (Sep. 3, 2020) (ADAMS Accession No. **ML20254A152**). Similarly, the NRC Staff's proposed rulemaking plan noted that "the development of requirements for fusion reactors could potentially include regulatory approaches similar to those for the regulation of accelerators." Memorandum from M. Doane, Executive Director for Operations, to the Commissioners, SECY-20-0032, Rulemaking Plan on "Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (RIN-3150-AK31; NRC-2019-0062)" at 7 (Apr. 13, 2020) (ADAMS Accession No. **ML19340A056**).

44 Whether an integrated safety analysis should be part of the licensing process is beyond the scope of this paper. While fusion plants do not raise criticality concerns, have much lower decay heat at and after shutdown than a fission reactor, and a far less significant inventory of dispersible radioactive material, likely making any accident requiring off-site response unrealistic, accident scenarios will exist and depend on facility design. As the Advisory Committee on Reactor Safeguards recently stated,

> Power densities and temperatures of the fusion blankets are similar to those seen in fission reactors, fusion reactors produce 14 MeV neutrons that will activate the surrounding structures producing significant radioactive material that represents an "afterheat" that must be managed, and this radioactive material could also be mobilized in an off-normal event or postulated accident. The fusion reaction requires kilogram levels of tritium in the facility. There are numerous energy sources whose failure can lead to mobilization of the radioactive materials in the plant (activated dust and tritium). Energy sources include coolant internal energy; chemical reactions of air or water with structural materials, plasma facing components, and reactive coolants; and magnet energy.

Letter from M. Sunseri, Chairman, Advisory Committee of Reactor Safeguards, to K. Svinicki, Chairman, NRC, "10 CFR Part 53 Licensing and Regulation of Advanced Nuclear Reactors" at 3 (Oct. 21, 2020) (ADAMS Accession No. **ML20295A647**).