Commonwealth Fusion Systems

117 Hospital Road, Devens, MA 01434

March 6, 2024

Mr. John Lubinski
Director, Office of Nuclear Materials Safety and Safeguards
US Nuclear Regulatory Commission
Washington, DC 20555-0001

RE: Preliminary Rulemaking Process for a Regulatory Framework for Fusion Systems
Docket No. NRC-2023-0071

Mr. Lubinski:

Commonwealth Fusion Systems ("CFS") offers its perspective on the preliminary rulemaking activities that your office has undertaken to implement the Nuclear Regulatory Commission's ("NRC" or "Commission") directive to establish a technology-inclusive regulatory framework for commercial fusion energy systems.[1] CFS appreciates your engagement and interest on this topic of critical importance to the emerging fusion energy sector in the United States. A comprehensive, predictable, and efficient regulatory foundation is critical for a new energy technology, like fusion, to move from demonstration projects to the marketplace as safely and quickly as possible. CFS has been engaged with the Commission on this issue for nearly four years and remains committed to achieving the right regulatory outcome for fusion energy to the benefit of the new fusion industry, the American people and the global energy market. CFS is taking the opportunity to follow up on some of the points that surfaced during the Commission's most recent public meeting on fusion energy regulation.[2]

CFS' overarching goal in this regulatory process is to ensure the regulatory program for commercial fusion protects public health and safety, worker safety, and the environment, while striking the right balance of rulemaking durability and regulatory flexibility that supports continuous innovation and access to this game changing technology. For these reasons, CFS endorses the December 15, 2023 letter from the Fusion Industry Association describing the consensus viewpoint of the fusion industry.[3] CFS is writing separately to emphasize the importance of explicitly placing fusion energy within the byproduct materials framework by tying fusion to the regulatory definition of "particle accelerators" for two main reasons:

- To shore up the statutory basis for the byproduct material approach to fusion energy; and
- To ensure that NRC, the Agreement States, and the entire regulated community can rely on the decades of practice, precedent, and experience that underpins particle accelerator materials licensing, operation, and decommissioning.

---

[1] NRC SRM-SECY-23-0001 (April 13, 2023), https://www.nrc.gov/docs/ML2310/ML23103A449.pdf.
[2] NRC Public Meeting on the Regulatory Framework for Fusion Systems (Jan. 17, 2024), https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML23355A144.
[3] Letter from A. Holland to J. Lubinski (Dec. 15, 2023), https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML23354A236.

I. A direct tie to "particle accelerators" solidifies the statutory foundation for placing materials licensing for fusion machines[4] in a byproduct materials framework.

The Energy Policy Act of 2005 (EPAct 2005) modified the Atomic Energy Act's definition of "byproduct material" to include "any material that (i) has been made radioactive by use of a particle accelerator; and (ii) is produced, extracted, or converted after extraction, before, on, or after the date of enactment of this paragraph for use for a commercial, medical, or research activity."[5] Congress's action to incorporate accelerator-activated material within the definition of federally regulated byproduct material made clear the intention of Congress for federal law to "occupy the field" with regard to accelerator-produced byproduct material while leaving decades of regulation of such material largely undisturbed.

However, Congress left NRC with substantial discretion to define apparatus that would be considered "particle accelerators." NRC defined "particle accelerators" to be "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. For purposes of this definition, accelerator is an equivalent term."[6] Because the Commission decided to place fusion machines in the byproduct material framework, NRC appears to have exercised this discretion further by directing Commission staff to develop a limited-scope rulemaking to place fusion systems within the byproduct material framework. CFS is not aware of a stronger statutory basis for NRC to regulate fusion machines within the byproduct material framework. An explicit tie between the definition of "fusion machines" and "particle accelerator" (as CFS and the FIA have called for) as referenced in the Atomic Energy Act and defined by NRC is critical in order to provide the regulatory certainty for the emerging US fusion energy industry.

A clearer tie between "fusion machine" and "particle accelerator" is also more closely aligned with the direction of the Commission in SRM-SECY-23-0001. The Commission directed staff to follow Option 2, use of the byproduct material framework, for fusion energy via a limited-scope rulemaking.[7] The rulemaking plan for Option 2 clearly contemplates "updating the definition of 'particle accelerator' to explicitly define radioactive material associated with the operation of a commercial fusion energy device as byproduct material."[8] CFS sees no reason to discard this portion of the rulemaking plan and believes that the Commission's final rulemaking text should clearly categorize material made radioactive by use of a fusion machine as byproduct material. In fact, the recent

[4] CFS recognizes that NRC has used "fusion energy system" or "fusion system" to refer to fusion energy machines. While "fusion system" may be an acceptable term in a narrow regulatory context, CFS agrees with the Fusion Industry Association that "fusion machine" is a more accurate characterization of the fusion apparatus in question, in the same way that NRC has defined a "particle accelerator" as a "machine."

[5] Atomic Energy Act of 1954, § 11(e)(3)(B), 42 U.S.C. § 2014(e)(3)(B).

[6] 10 C.F.R. § 30.4.

[7] SRM-SECY-23-0001 (noting the "limited-scope rulemaking approved under Option 2"). NRC staff described the rulemaking plan for Option 2 as "similar to that provided for Option 3, omitting the development of decision criteria for when fusion energy systems should be considered utilization facilities." SECY-23-0001 at 17.

[8] *Rulemaking Plan for Fusion Energy Systems*, SECY-23-0001 Enclosure 1 at 3.

preliminary rulemaking text shared to date does not directly link fusion machines with the definition of "particle accelerator" which appears to be inconsistent with the direction to the staff via SRM-SECY-23-0001.

CFS is aware that some NRC staff have raised the concern that some fusion machines, which do not use deuterium-tritium reactions to produce thermal energy and neutrons via their primary fusion reaction, may not be considered particle accelerators as NRC has traditionally interpreted the term.[9] This concern does not align with the scientific realities of the four known fusion fuel cycles and fails to take into account that all fusion machines generate neutrons (via either primary or secondary reactions) which will activate surrounding materials in the course of commercial operations. Arguably, in the commercial fusion context, this material will be "made radioactive" for a "commercial" activity, i.e., the generation and sale of electricity or other energy products like heat from fusion reactions. As a result, even fusion machines that would not produce neutrons through their primary reactions fit the statutory definition of byproduct material due to their making of radioactive material to produce and sell electricity.

Even applying the Commission's historic gloss on the term, which asserts that the accelerator-activated material is only byproduct material under the Atomic Energy Act if the accelerator is operated to create the material for its radioactive properties,[10] all fusion systems utilizing the four known fusion fuel cycles would be deemed particle accelerators because they all intentionally or inadvertently create radioactive materials for their radioactive properties, through the generation of tritium and other fuel cycle constituents (e.g., carbon-11 that decays into boron-11 for proton-boron-11 fusion) or the activation of material through exposure to neutrons, in the course of accelerating particles for a commercial activity.[11] A discussion of all four credible fusion fuel cycles and their creation of byproduct materials is discussed below:

- For the **deuterium-deuterium** fuel cycle, 50% of the primary reactions create a neutron and the other 50% create tritium. That tritium is likely, dependent on system details, to fuse with deuterium and produce a neutron;
- For the **deuterium-tritium** fuel cycle, a neutron is created in essentially 100% of deuterium-tritium fusion reactions;[12]
- For the **deuterium-helium3** fuel cycle, the helium-3 fuel is obtained through the radioactive decay of tritium. The tritium used to produce helium-3 must be either produced in a fusion machine or fission

[9] SECY-23-0001 at 10.
[10] Requirements for Expanded Definition of Byproduct Material, 72 Fed. Reg. 55,864 at 55,868 (Oct. 1, 2007).
[11] CFS does not believe that it is accurate to characterize any fusion machine as "aneutronic" given the non-trivial neutron production from all forms of commercializable fusion energy.
[12] NRC staff appears to recognize that deuterium-tritium fusion systems will qualify as particle accelerators because they will produce tritium, a radioactive material, intentionally in order to sustain fusion reactions for a commercial or research activity. SECY-23-0001 at 10.

reactor that also produces neutrons. This fuel cycle also has the other neutron production mechanisms associated with the deuterium-deuterium fuel cycle as secondary reactions;[13] and

- For the **proton-boron-11** fuel cycle, the primary reaction creates an excited carbon-12, this is the fusion step, which then radioactively decays to beryllium-8 plus an alpha and then beryllium-8 decays further into two alphas. Gamma radiation accompanies these decays. The gamma and alpha emissions are all used commercially to generate heat and energy.[14] The primary reaction also has a branch that produces a neutron and a gamma emitting carbon-11 with a half-life of 20 minutes.[15] A secondary reaction also occurs in a practical proton-boron-11 plasma where an alpha and boron-11 react to form a neutron and nitrogen-14. Calculations show that at least 0.1% of the reactions in a proton-boron-11 plasma produce neutrons.[16]

In the same way that all fusion fuel cycles meet the historic definition of "particle accelerator," so do all fusion machine designs that CFS is aware of. CFS believes that all proposed technical approaches to fusion would appropriately fit within this definition of particle accelerator. The appendix to this submission maps the different approaches to fusion energy against the characteristics in the Commission's definition of a "particle accelerator." We are available to have more detailed, technical discussions with NRC staff on the creation of byproduct materials through all fusion fuel cycles and technical approaches at your convenience.

CFS believes that the definition of "fusion energy machine" as proposed in H.R. 5244, the Fusion Energy Act, recently agreed to by the House Energy and Commerce Committee[17] and adopted by the U.S. House of Representatives,[18] comprehensively addresses fusion energy in a technology-inclusive and technology-neutral manner. That definition, as amended, reads as follows:

> Fusion Energy Machine.—The term 'fusion energy machine' means a particle accelerator that is capable of—
>
> (1) transforming atomic nuclei, through fusion processes, into other elements; and
>
> (2) directly capturing and using the resultant products, including particles, heat, and other electromagnetic radiation, for a commercial or industrial purpose.[19]

[13] A private company pursuing deuterium-helium-3 fusion, Helion Energy, has explained to NRC that it believes its fusion system will qualify as a particle accelerator due to its production of tritium for later commercial use after it decays into helium-3. Letter from S. Desai to S. Lynch at 8 (Aug. 12, 2022), https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML22243A083.
[14] https://doi.org/10.1016/j.physletb.2010.12.015
[15] https://doi.org/10.1016/0020-708X(74)90049-0
[16] Heindler and Kernbichler, Proc. 5th Intl. Conf. on Emerging Nuclear Energy Systems, 1989, pp. 177–82.
[17] https://trahan.house.gov/news/documentsingle.aspx?DocumentID=3063
[18] H.R. 6544, Atomic Energy Advancement Act.
[19] H.R. 5244, The Fusion Energy Act.

CFS encourages the NRC staff to adopt this definition and include it within 10 C.F.R. Parts 20 and 30 to create a sturdy statutory foundation for the Commission's regulation of fusion energy. The proposed definition to tie fusion machines to particle accelerators would solidify the statutory foundation for placing materials licensing for fusion machines in a byproduct materials framework. This approach would fit appropriately within NRC's historical discretion in defining which devices would be considered particle accelerators, comply with the Commissioner's directive in SRM-SECY-22-0001, and aligns with Congressional intent under NEIMA and the pending Fusion Energy Act.

II. NRC's rulemaking for fusion energy should permit all stakeholders to rely on the practice, precedent, and experience that underpins the materials licensing, operation, and decommissioning of particle accelerators.

As noted above, Congress expanded NRC's jurisdiction to include material made radioactive by a particle accelerator for a commercial, medical, or research activity in EPAct 2005. These devices, and the material that they activate, had been within the purview of state regulation for decades,[20] and indeed the devices themselves remain within the purview of state oversight. For many years, fusion research machines have been regulated in this particle accelerator context, building familiarity with this category of machine, and the hazards their operation can present, among the regulators, the regulated community, and the public. Relevant to the Commission's direction to staff in its decision on fusion energy to account for "the existence of fusion systems that already have been licensed and are being regulated by the Agreement States, as well as those that may be licensed prior to the completion of the rulemaking," these fusion machines have been regulated within the particle accelerator framework for decades.

CFS is currently constructing SPARC, its fusion demonstration machine within this existing licensing framework in Devens, Massachusetts. Leveraging the decades of familiarity with precedent in the particle accelerator sector has been crucial for assembling the license application. From project design to engagement with the state regulator to planning the eventual end of operations and decommissioning, CFS and its regulator have regularly relied on precedent and practice in the particle accelerator space. As CFS has communicated in public fora with NRC and stakeholders, reliance on accelerator-focused guidance material like NUREG-1556 Volume 21 has been indispensable for the SPARC licensing process. CFS strongly agrees with and endorses NRC staff's initial steps to build the new fusion-specific volume of NUREG-1556 on the experience embodied by Vol. 21.

However, CFS is concerned that the rulemaking discussion undertaken to date could erode confidence that fusion developers, and all segments of the fusion-supporting economic ecosystem, can utilize the practices used for decades in the fusion research and particle accelerator context. By failing to place fusion energy machines clearly within the particle accelerator definition, NRC is signaling that fusion produced radioactive materials are some kind of new category of byproduct material and not, as the Commissioners indicated, a part of the familiar category of accelerator-produced radioactive material. This approach increases, rather than decreases, regulatory

[20] In the Energy Policy Act of 2005, Congress emphasized the importance of the pre-existing state programs for accelerator-activated material by expressly directed NRC to "use model State standards" to implement the expanded definition of byproduct material in the Commission's regulations.

uncertainty for fusion energy developers and the industries that have been supporting the fusion sector for decades via the particle accelerator framework.[21]

One example of this disconnect between existing treatment of particle accelerators and the proposed rulemaking for fusion machines is in the available pathways for the long-term management of fusion-activated byproduct material. In EPAct 2005, Congress specifically authorized materials licensees producing byproduct material by accelerators to dispose of such materials either at facilities licensed by the Commission or an Agreement State or "at a disposal facility in accordance with any Federal or State solid or hazardous waste law, including the Solid Waste Disposal Act."[22] This congressional action recognized the long standing disposal pathway for these materials and allowed that practice to remain undisturbed by the expansion of NRC's jurisdiction to accelerator-activated material. NRC implemented this approach in a 2007 update to its Part 20 regulations: "A licensee may dispose of byproduct material, as defined in paragraphs (3) and (4) of the definition of Byproduct material set forth in § 20.1003, at a disposal facility authorized to dispose of such material in accordance with any Federal or State solid or hazardous waste law, including the Solid Waste Disposal Act, as authorized under the Energy Policy Act of 2005."[23] The provision in the EPAct 2005 and the implementing regulation forms the basis for the nation's management of accelerator-activated byproduct material.

CFS's understanding from Commission staff's public presentation on January 17, 2024, is that activated byproduct material from "near-term fusion systems," which includes machines like CFS' ARC power plants, will be able to be disposed of via transfer to an "authorized recipient." Those authorized recipients include both facilities licensed pursuant to 10 C.F.R. Part 61 and facilities regulated by state or federal authorities which are permitted to receive such activated material.

In the current rulemaking effort on fusion energy, NRC staff has proposed the following addition to 10 C.F.R. § 20.2008: "[w]aste resulting from fusion systems must be disposed of in a disposal facility that has completed a site-specific intrusion assessment that demonstrates the projected dose to an individual who inadvertently intrudes into the waste at the facility will be less than 5 millisievert (mSv) per year." Assuming that this proposal should be read in conjunction with existing statute and regulation, this language appears to assume that there could be fusion machines which are not particle accelerators, a concern which has been addressed above. If the staff's addition was not intended to exclude materials activated by certain fusion energy machines from being disposed as accelerator-produced radioactive materials, then the presence of this rulemaking text would be

[21] This approach also contravenes the Commission's Principles of Good Regulation. It does not meet the "Clarity" principle because it does not offer a logical or practical reason for treating fusion machines differently from particle accelerators. And it does not meet the "Reliability" standard because it exacerbates regulatory uncertainty for fusion machine developers by unjustifiably calling into question the applicability of practices and precedent developed for particle accelerators despite numerous fusion machines having been regulated in this context for decades.

[22] Section 651(e)(3) of the Energy Policy Act of 2005 ("EPAct 2005"). EPAct 2005 also excluded applicability of the interstate low-level waste compact system to these materials. *Id.*

[23] 10 C.F.R. § 20.2008(b).

superfluous. Further, this proposed addition has the potential to conflict with the waste provisions of the EPAct 2005, which could create unintended regulatory uncertainty for all stakeholders.[24]

Proposed section 20.2008(c) appears to be intended as a backstop to ensure that any future fusion machines that are not particle accelerators could still dispose of their activated materials at the standard low-level radioactive waste facilities licensed by the Commission pursuant to 10 C.F.R. Part 61.[25] However, as detailed above, there is no reason that any fusion machine cannot be fairly characterized by the existing definitions of "particle accelerator" in Parts 20 and 30 of the Commission's regulations. If NRC were to adopt the regulatory direction suggested by the Fusion Industry Association and embodied in the Fusion Energy Act, which ties the definition of fusion energy machine to particle accelerators, this proposed rulemaking language change to 10 C.F.R § 20.2008 becomes unnecessary and can be removed from the proposal.

Reliance on the particle accelerator precedent and practice for fusion machines also will avoid confusing stakeholders, from federal/state regulators and policymakers to the general public, because all are already familiar with the licensing framework for particle accelerators. Leveraging the particle accelerator framework will most efficiently and robustly provide the necessary protection for public health, worker safety, and environmental protection while also providing regulatory certainty for the nascent fusion industry.

CFS stands ready to engage with the Commission and all other stakeholders to establish a strong statutory foundation for the regulation of fusion energy in the United States. CFS is also planning to offer more detailed input on the composition of the NUREG-1556 Vol. 22 under development for fusion machines. Thank you for your consideration and please reach out if you have any questions.

Sincerely,

Tyler Ellis, Ph.D.

Commonwealth Fusion Systems LLC

CC: Chair Christopher T. Hanson, NRC

Commissioner Annie Caputo, NRC

Commissioner Bradley R. Crowell, NRC

---

[24] 42 U.S.C. § 2021b(9)(B).

[25] CFS recognizes that fusion developers could pursue a sort of alternative disposal plan pursuant to 10 CFR § 20.2002, but requiring such an alternative approach for any particle accelerator, including fusion machines, conflicts with current federal statute and regulation which directly exempts licensees for accelerator-activated material from defaulting to Part 61 regulation.

Commissioner David A. Wright, NRC

Daniel H. Dorman, Executive Director for Operations, NRC

Brooke Clark, General Counsel, NRC

Catherine Haney, Deputy Executive Director, NRC

Theresa Clark, Deputy Director, NRC

Duncan White, Technical Lead, NRC

Dennis Andrukat, Rulemaking Project Manager, NRC

Appendix: All Fusion Approaches are "Particle Accelerators"

This appendix maps the general categories of fusion approaches, with the more specific categories and companies also listed, to show that all technical approaches to fusion are well encapsulated with the NRC's current definition of Particle Accelerator. 10 C.F.R. § 30.4 defines Particle Accelerator as "… 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. For purposes of this definition, accelerator is an equivalent term." The National Ignition Facility was not included in the table below because it is not a company, but if it were included, it would fit under the Inertial Confinement Laser Compression approach.

Recognizing that NRC staff is considering removing the reference to "energies usually in excess of 1 megaelectron volt" from the Commission's regulations, for purposes of this comparison, all fusion reactions deemed practical for energy production release particles at energies greater than 1 megaelectron volt. Whether or not the Commission ultimately removes this portion of the definition of "particle accelerator," all fusion approaches would satisfy this prong of the existing regulatory definition.

	NRC Characteristics of a Particle Accelerator			
Fusion Approach	Machine (Companies)	Capable of accelerating electrons, protons, deuterons, or other charged particles	In a vacuum	Discharging the resultant particulate or other radiation into a medium
Magnetic Confinement	Tokamak (CFS, Energy Singularity) Spherical Tokamak (Tokamak Energy, ENN) Stellarator (Type One, Renaissance Fusion, Helical Fusion, Proxima Fusion, Stellarex, Thea Energy, Gauss Fusion)	Uses magnetic fields to confine the fusion plasma and radio frequency heating and/or high-energy neutral beams to accelerate charged particles towards one another to induce fusion	Reactions take place in a vacuum chamber	Resultant particles discharged into the surrounding vacuum vessel, blanket or other direct energy conversion mediums (e.g. electrodes or similar components)

	Field-reversed configuration (TAE, Princeton Fusion Systems) Magnetic Mirror (Realta Fusion) Levitated Dipole (Openstar Technologies) Cusp (Novatron, Polywells, Lockheed Martin (formerly)) Hybrid Electrostatic (Avalanche)			
Inertial Confinement	Laser Compression (Blue Laser Fusion, Ex-Fusion, Focused Energy, HB11, Laserfusionx, Longview Fusion Energy Systems, Marvel Fusion, Xcimer Energy) Projectile Compression (First Light Fusion)	Uses lasers, shockwaves or other compression methods to accelerate charged particles towards a central point where conditions necessary for fusion are achieved	Reactions take place in a vacuum chamber	Resultant particles discharged into the surrounding vacuum vessel, blanket or other direct energy conversion mediums (e.g. electrodes or similar components)
Magneto-Inertial Confinement	Liquid Compression (General Fusion) Field-Reversed Configuration	Uses a combination of magnetic confinement (magnetic fields and radio frequency heating)	Reactions take place in a vacuum chamber	Resultant particles discharged into the surrounding vacuum vessel, blanket or other direct energy

	(Helion, Compact Fusion Systems) Z-Pinch (Zap Energy, MIFTI) Plasma Jet (Hyperjet Fusion) Magnetized Liner Inertial Fusion (Fuse)	and inertial confinement techniques (lasers, shockwaves, pulsed magnetic fields or other compression methods) to accelerate charged particles towards one another to induce fusion		conversion mediums (e.g. electrodes or similar components)