Commonwealth Fusion Systems

148 Sidney Street, Cambridge, MA 02139, USA

August 16, 2022

The Honorable Christopher T. Hanson
Chairman
U.S. Nuclear Regulatory Commission
Mail Stop O-16 B33
Washington, D.C., 20555-0001

RE: Developing a Regulatory Framework for Fusion Energy Systems

Chairman Hanson:

Thank you for the opportunity to provide further input as you and members of your team implement the Nuclear Regulatory Commission's ("NRC" or the "Commission") directive to evaluate regulatory frameworks for fusion energy systems. Commonwealth Fusion Systems, LLC ("CFS") appreciates NRC staff members' efforts on this matter, and we welcome the opportunity to provide additional information outlining our views on the appropriate approach to a regulatory framework for fusion energy systems in the United States. This letter is intended to be a supplement to CFS's contributions[1] to the ongoing dialogue regarding the regulation of fusion energy power systems and to support the NRC fusion working group's evaluation of these issues.[2]

CFS is currently building a fusion energy demonstration facility, called SPARC,[3] in Massachusetts and we are designing our commercial fusion power plant, called ARC. We have recently demonstrated the critical component in the development of our technology (high temperature superconducting ("HTS") magnets), underscoring the fact that we can achieve net fusion energy from a significantly smaller device and on a considerably faster timeline compared with other fusion energy approaches.[4] As discussed at prior public meetings with NRC staff, CFS believes that the materials licensing program in Part 30 of the Commission's regulations is appropriate for commercial fusion. NRC staff recognized during its May 2021 meeting with the Commission's Advisory Committee on Reactor Safeguards that the materials licensing program, including licensing activities delegated to states, can

[1] CFS presented information at the NRC virtual public meetings on January 26, 2021, on March 30, 2021, on October 27, 2021, on March 23, 2022, and on June 7, 2022.

[2] CFS notes that this submission is on our behalf only and does not purport to represent the views of the growing fusion sector in the United States, including the membership of the Fusion Industry Association ("FIA"). However, we believe that the views expressed in this submission are wholly consistent with the FIA's regulatory consensus position adopted in the organization's white paper and presented to NRC staff members during public meetings over the last two years.

[3] CFS has placed substantial scientific and technical information regarding the development of the SPARC facility in the public domain, including a series of peer-reviewed papers in the Journal of Plasma Physics, Volume 86, Issue 5, (Sept. 29, 2020), https://www.cambridge.org/core/journals/journal-of-plasma-physics/collections/status-of-the-sparc-physics-basis.

[4] Commonwealth Fusion Systems Creates Viable Path to Commercial Fusion Power with World's Strongest Magnet (Sept. 8, 2021), https://cfs.energy/news-and-media/cfs-commercial-fusion-power-with-hts-magnet.

accommodate permitting for commercial fusion machines.[5] And as shown below, NRC has the authority and regulatory structures in place to implement this approach for commercial fusion energy.

CFS offers the views in this letter with several goals in mind:

(1) Obtain regulatory clarity for fusion energy on a timeline that supports both the White House's Bold Decadal Vision for Commercial Fusion Energy[6] in the United States and current private fusion industry plans;[7]

(2) Use the existing specific licensing process for materials licensees, as well as conditions addressing project-specific issues and NUREG guidance processes, in order to avoid an overly prescriptive regulatory approach and allow the fusion community to build operational experience;

(3) Encourage NRC to exercise its existing statutory authority under the Atomic Energy Act ("AEA") and minimize the need for changes to the Commission's existing regulations;

(4) Leverage expertise across the Agreement State community; and

(5) Prompt the United States to maintain compatibility with global fusion regulation, specifically as the United Kingdom advances a materials licensing approach to fusion.[8]

CFS believes that adopting the approach outlined during its presentations at the NRC's public meetings and further described below will meet these goals, allow NRC to succeed in its critical safety and security mission while complying with its Congressional mandate, and establish a vibrant fusion industry for the United States.

This letter seeks to address a number of questions that have come up during the course of NRC's public meeting process and provide more additional information regarding regulatory issues related to fusion. After providing some background information on fusion and CFS's activities, this letter explains why a materials licensing approach is proper and the most viable solution for commercial fusion considering that commercial fusion machines do not create a fission chain reaction, do not produce high-level waste, do not fit the definition of utilization facility under Parts 50 and 52 and are not significant to the common defense and security.

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[5] Official Transcript of Proceedings for the Advisory Comm. on Reactor Safeguards, Nuclear Regulatory Comm'n at 16 (May 6, 2021), https://www.nrc.gov/docs/ML2115/ML21154A041.pdf.

[6] Readout of the White House Summit on Developing a Bold Decadal Vision for Commercial Fusion Energy, THE WHITE HOUSE (Apr. 19, 2022), https://www.whitehouse.gov/ostp/news-updates/2022/04/19/readout-of-the-white-house-summit-on-developing-a-bold-decadal-vision-for-commercial-fusion-energy/.

[7] The vast majority of the private fusion industry expects commercial fusion energy to enter the energy market by the 2030s. *The Global Fusion Industry*, FUSION INDUS. ASS'N at 11 (July 2022), https://www.fusionindustryassociation.org/copy-of-about-the-fusion-industry.

[8] The United Kingdom has indicated that it believes that it should regulate fusion outside the conventional nuclear fission energy context. Regulatory Horizons Council: Report on Fusion Energy at 6 (May 2021), https://www.gov.uk/government/publications/regulatory-horizons-council-report-on-fusion-energy-regulation.

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I. Introduction

Congress directed NRC to establish a "technology-inclusive[] regulatory framework for optional use by commercial advanced nuclear reactor applicants" by December 31, 2027.[9] NEIMA defines "advanced nuclear reactor" to include "fusion reactors."[10] The statute does not require that NRC treat fusion systems the same way as fission

[9] Nuclear Energy Innovation and Modernization Act ("NEIMA"), Pub. L. No. 115-439, § 103(a)(4).

[10] *Id.* § 3(1). The statute does not define the types of devices or equipment that fall within the ambit of "fusion reactor." CFS is aware that NRC staff has proposed regulatory language that would define "fusion reactor" as a "reactor that uses a process to combine two lighter atomic nuclei to form a heavier nucleus, while releasing energy." NRC Staff, Preliminary Proposed Rule Language 10 C.F.R. Part 53, ADAMS Accession No. ML21112A195 (Apr. 23, 2021). As a preliminary reaction to this language, CFS believes that this definition is too broad since it would include all fusion experimental research facilities in the US, and even hobbyist machines like fusors. *See, e.g.*, Dan Spangler, *Learn How to Build a Nuclear Fusor*, MAKE MAGAZINE (Nov.

reactors and the legislation makes clear that this framework is optional for any advanced reactor (fission or fusion).[11] Developers of fusion energy systems could seek permitting approval pursuant to current regulatory programs, in the same way that fission developers could seek licensing approval under existing Part 50 rules rather than the new optional framework that NEIMA mandates.

CFS appreciates the analysis that NRC performed to produce SECY-20-0032's plan to develop the Congressionally mandated regulatory optional framework for licensing and regulation of advanced nuclear reactors as a new Part 53 of its regulations and welcomes the opportunity to continue participating in this process. CFS further appreciates and agrees with your request that NRC staff consider using existing regulations at Parts 20 and 30 to regulate fusion energy systems in your comments approving several facets of SECY-20-0032.[12]

It is critical that NRC get this regulatory approach right. As Commissioner Annie Caputo put it, NRC "must recognize the impact of [the Commission's] work on the future" of advanced reactors in the United States.[13] The private U.S. fusion industry is running dual races to: (1) develop and deploy this crucial, safe and zero-carbon baseload technology quickly enough to matter in the fight against climate change, and (2) win the global race with other countries, including China, to demonstrate and commercialize fusion energy. CFS believes that getting the framework right is in the best interest of ensuring public health and safety as well as the future viability of the technology as a source of clean and reliable energy. Cognizant of Commissioner Caputo's reminder that "NRC's role cannot be a promotional one," CFS requests that the Commission review the information that we have provided and will continue to provide throughout the ongoing dialogue with the NRC to explain our technology and recognize the impact of these regulations on the US fusion energy industry and the nation as a whole while still ensuring the necessary protection to the public's health and safety.

II. Background on the U.S. Private Fusion Industry and CFS

Although all participants in the US fusion sector are approaching fusion power systems using different designs and different fuels, all US private fusion developers are using common key design drivers that are different from and present a completely different risk profile than fission plants.[14] Furthermore, all of the private fusion ventures that

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1, 2013), https://makezine.com/projects/nuclear-fusor/ (describing the process to build a table-top fusion machine which would meet the proposed definition of "fusion reactor" but not produce net energy). Instead, the focus should be on commercial net energy fusion and the radioactive materials associated with those commercial fusion activities. It would be inappropriate to include fusion experimental machines in Part 53 or any other portion of this current regulatory exercise because they are already comprehensively covered by existing federal and state rules and have been for decades.

[11] NEIMA, § 103(a)(4).

[12] SECY-20-0032, Commissioner Hanson Response Sheet, ADAMS Accession No. ML20254A152 (Sep. 3, 2020).

[13] *Id.*, Commissioner Caputo Response Sheet, ADAMS Accession No. ML20254A150 (Aug. 26, 2020).

[14] Then-Commissioner Hanson highlighted the facts that fusion uses a "fundamentally different atomic process" from fission, fusion reactors would present a completely different risk profile compared with fission reactors, fusion reactors will not use special nuclear material or source material, and fusion reactors do not create risk for criticality accidents or decay heat removal. *Id.*, Commissioner Hanson Response Sheet, ADAMS Accession No. ML20254A152. For a more complete outline of the scientific and engineering differences between fusion and fission, *see* FIA Regulatory White Paper at 10–15 (June 2020), https://www.fusionindustryassociation.org/post/fusion-regulatory-white-paper.

CFS is aware of are pursuing fusion concepts and device designs that are very different from the large international experiments, such as the International Thermonuclear Experimental Reactor ("ITER")[15] and the even larger Demonstration Power Station ("DEMO").[16] Given fusion's lower risk profile compared to fission and private fusion's significantly smaller size compared to ITER and DEMO, it is reasonable to regulate private fusion under a Part 30 materials based framework.

To CFS's knowledge, there are no private fusion companies which are proposing to construct either an ITER or DEMO-like facility in the United States. Given the estimated $65 billion cost of ITER,[17] and the fact that DEMO would likely cost more since it is larger than ITER, it is extremely unlikely that any privately funded company would have either the balance sheet or interest to deploy this technology approach. Recent technological advances make it less and less likely that any private developer would attempt to convert such experimental facilities into commercial ones in the United States or anywhere else. Therefore, basing analysis of private fusion safety concepts or the related regulatory approaches on assumptions underpinning ITER and DEMO creates a false impression as to the scale of facilities and potential risks that private fusion approaches might create.

A. Rapid Technical Progress Signals Progress Beyond ITER and DEMO Designs

CFS is developing a compact tokamak design using HTS magnets, which allow a high degree of plasma confinement in a relatively small device. CFS's initial machine, SPARC, will demonstrate net energy from deuterium-tritium fusion reactions in 2025. Then, in the early 2030s, CFS plans to demonstrate a commercial-scale tokamak called ARC to produce reliable, dispatchable, carbon-free energy.

CFS's advances in HTS magnet and other technologies unlock several advantages over previous tokamak system designs. Specifically, the HTS magnets improve plasma confinement and device performance, allowing for higher efficiency of fusion reactions in a smaller space compared with conventional magnetic confinement devices. CFS is also designing advanced tritium blanket and handling systems which will use the tritium as it is generated. The expected results of these improvements are smaller tokamak facilities, smaller tritium inventories, smaller activated waste volumes, and safer facilities that do not create any risks for the off-site public. CFS's new HTS magnet technology renders the ITER and DEMO designs as one-of-a-kind machines since it is now possible to design tokamaks to demonstrate net fusion energy with 1/40 of the volume of ITER at a dramatically lower cost.

SPARC is being regulated by the Commonwealth of Massachusetts pursuant to the Commonwealth's agreement with the NRC to accept delegated authority over certain activities covered by the AEA, including materials licensing

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[15] Facts & Figures, ITER, https://www.iter.org/FactsFigures.

[16] Stuart Nathan, *Beyond ITER – next steps in fusion power*, THE ENGINEER (Jan. 3, 2019), https://www.theengineer.co.uk/beyond-iter-next-steps-in-fusion-power/. Importantly, much of the scientific literature has focused on evaluating ITER and the hypothetical designs for DEMO. However, CFS and other private fusion ventures in the United States are pursuing much smaller fusion energy machine designs than either ITER or DEMO.

[17] *Senate Appropriators Grill Energy Sec'y Perry on Proposed R&D Cuts*, AM. INST. OF PHYSICS (Apr. 19, 2018), https://www.aip.org/fyi/2018/senate-appropriators-grill-energy-secretary-perry-proposed-rd-cuts

as embodied by Part 30 of the Commission's rules.[18] Massachusetts' overarching governing regulation for its Radiation Control Program is 105 CMR Part 120 that regulates the control of radiation. This process has been and will continue to be informed by NUREG-1556 Volume 21, which contains accelerator licensing guidance.[19] NRC staff has indicated that it agrees with Massachusetts's oversight of the SPARC device.

B. Maintaining a Fusion Plasma Does Not Create Anything Like a Fission Chain Reaction

Achievement of a fusion plasma which is dominantly heated by its own reaction products has been a key goal of fusion scientists and engineers for decades and will be critical to development of an economic fusion energy machine. Sometimes termed a "burning plasma," this goal refers to a plasma physics regime in which internal heat liberated from fusion reactions provides more heat to the plasma than external heat sources, such as radio frequency heating. In fusion energy machines using deuterium-tritium reactions, such as SPARC, ARC, and ITER, this internal heating is predominantly due to charged alpha particles (i.e., helium nuclei) which carry ~20% of the fusion reaction energy while the other ~80% of the fusion reaction energy is carried out of the plasma by the neutron. In other words, a "burning plasma" requires that the fusion energy systems produce at least five times more fusion energy than is required to be input to run the facility, Q>5 where Q is the ratio of energy produced by the reaction to the energy required for the reaction. In essence, the amount of internal heating within a stable fusion plasma is a measure of the efficiency of the plasma core within a fusion energy machine.[20] In order to be a practical power plant due to energy conversion efficiencies, future fusion energy systems will need to produce at least ten times more fusion energy than is required to be input to run the facility, Q>10.

However, even if alpha particle internal heating is able to exceed plasma heating from external sources in SPARC, ARC, or other future commercial fusion energy machines, a fusion plasma is fundamentally different from a fission chain reaction that is familiar to the Commission and its staff. In a fission chain reaction, relatively large nuclei, such as uranium, absorb a neutron and split into two fission fragments, gamma rays, ~200 MeV of energy and ~2.5 neutrons. Those liberated neutrons go on to interact with and may split other large nuclei, releasing more neutrons which strike more nuclei, and so on until the fuel is spent or other conditions in the fissile material reduce the probability of the neutrons to fission other nuclei, ending the chain reaction.

In contrast to fission, a fusion plasma does not involve any neutron chain reaction and neutrons are not part of the self-heating process of a plasma. The charged alpha particles carry a relatively small amount of energy (~20%)

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[18] The NRC has authority to enter into agreements with states to delegate and discontinue its authority over byproduct material regulation and thereby empower states to become the primary regulators of such materials ("Agreement State Program"). 10 C.F.R. § 30.4; 42 U.S.C. § 2021(b)(1) ("Section 274"). The agreement between NRC and Massachusetts delegates authority to the Commonwealth over byproduct material, source materials, special nuclear materials in quantities not sufficient to form a critical mass, and licensing for low-level radioactive waste facilities. Commonwealth of Massachusetts: Discontinuance of Certain Comm'n Regulatory Authority Within the Commonwealth, 62 Fed. Reg. 16628 (Apr. 7, 1997).

[19] Regulators and applicants can also look to guidance in NUREG-1556 Volume 7 for R&D facility licensing guidance.

[20] Congress, DOE, and the NRC have not formally defined "burning plasma" or "ignition." But DOE's website gives a brief explanation of the concept of internal heat generation or a "burning plasma" and ignition concepts at https://www.energy.gov/science/doe-explainsburning-plasma.

compared to the released neutron (~80%). The neutrons are not bound by magnetic confinement because they have no charge, and thus do not interact with the magnetic fields confining the plasma, and end up leaving the plasma. A fusion energy machine can use the energy that neutrons carry to generate electric power and use the neutrons themselves to regenerate the tritium which can be recirculated to catalyze the fusion process. The alpha particles will remain suspended in the magnetically confined plasma and contribute some of their energy as heat to encourage further fusion reactions within the deuterium-tritium plasma.

Even if a fusion plasma no longer relies on outside heat sources, it remains a delicate wisp of hot gas which has an energy density less than that of boiling water. No amount of alpha particle heating could overcome a loss of vacuum and introduction of ambient air into the machine – a loss of vacuum in the vacuum vessel will cause the reaction to halt immediately. Likewise, a loss of power and subsequently magnetic confinement will cause the fusion plasma to touch the wall of the vacuum vessel and immediately cool down the plasma which stops the fusion reactions. Founded on the physics inherent to a fusion plasma, and in contrast to conventional fission reactors that rely on neutron-driven chain reactions, any failure mode of the fusion machine immediately halts the fusion reactions. There is absolutely no risk of a runaway chain reaction in a fusion energy machine.

C. SPARC and ARC Tritium Inventories Will Be Far Smaller Than ITER or DEMO

CFS's designs for SPARC and ARC call for a fraction of the tritium inventories as compared to ITER and what is anticipated for DEMO. SPARC's tritium inventory is estimated to be 10 grams, which is comparable to the tritium inventories of research devices, industrial research suppliers, and pharmaceutical manufacturers. In fact, some major commercial institutions have licenses to hold up to 10g of tritium within major urban areas and have maintained that tritium inventory safely for decades.

By comparison, ITER expects to hold an inventory of 5,000 grams of tritium and DEMO may have a tritium inventory of 15,000 grams. These estimates are dependent on the fueling efficiency, the burn fraction and the reserve inventory retained in storage for one day's operation. Even though ARC is a modestly larger fusion demonstration system than SPARC and will be capable of producing substantial excess energy for commercial purposes, its tritium inventory requirements are much lower than the tritium needs anticipated for the ITER and DEMO projects. Unlike experimental machines like ITER and DEMO, which must have large inventories of tritium and other fusion inputs on site in order to run repeated experiments that change the parameters of machine performance, commercial fusion energy machines using a deuterium-tritium reaction will use a completely different operational philosophy compared to ITER and DEMO. Instead of maintaining large inventories of tritium for extended operational campaigns, tritium use and generation will be tightly coupled in commercial fusion energy machines like ARC. Therefore, there will be no reason to have a large cache of tritium on site to support variable machine operations, instead relying on consistent operations that use, generate, and recirculate tritium rapidly and constantly.

CFS plans to use high-temperature interior components in its vacuum vessel and other plasma-facing materials, which minimizes the retention of the tritium inventory in the vacuum vessel wall. CFS is also designing a simpler tritium recovery and handling system, including a molten salt tritium breeding blanket, which will circulate and utilize the tritium as it is generated, resulting in a much smaller tritium inventory than either ITER or DEMO which were designed to maintain a large tritium inventory to draw from as they frequently start up and shut down for experimental purposes. In addition, ARC will have a lower thermal power load compared with DEMO. As a result of these advancements, the smaller tritium inventories for SPARC and ARC reiterates the substantial distinctions from DEMO and ITER.

D. Activated Waste Volumes Are Anticipated to Be Far Lower Than ITER or DEMO

CFS is using a high-field approach to its tokamak design, meaning that the plasma confinement and performance depends on high-strength magnetic fields that the HTS magnets will generate. This approach will allow SPARC to achieve and maintain a high-performance fusion plasma in a significantly smaller fusion energy system than previous designs like ITER and DEMO. In fact, preliminary calculations indicate that SPARC's power core components will generate only 5m^3 of low-level waste over its operational lifetime.[21] Likewise, ARC is expected to generate a small fraction of the low level activated waste that designers expect for ITER or DEMO.

CFS expects that all of the activated material at SPARC and ARC will comply with the standards for low level waste under Part 61 of the Commission's regulations. For SPARC, the majority of this activated material will be classified as Class A low level waste. No waste from SPARC or ARC would be classified as high-level waste[22] since fusion does not utilize any special nuclear material or source material. Therefore there is nothing about fusion's waste profile which demands a change to the regulatory approach for commercial fusion.

E. SPARC and ARC Meet Regulatory Standards for Risks to Off-Site Public

SPARC and ARC will use a design that complies with all regulatory standards for risks to the off-site public. To comply with Part 30, the Commission's regulations require license applicants to demonstrate that the maximum dose to a member of the general public be less than:

Mode	Dose Pathway to Off-site Public	Regulatory Limit or Guideline (mrem)
Chronic	Annual effluent	10
Chronic	Annual effluent plus direct	100
Chronic	Direct dose in any hour	2
Accident	Accident	1,000

[21] *See* 10 C.F.R. § 61.55.
[22] 42 U.S.C. § 10101(12).

If a facility is designed to stay under these limits, then neither public safety nor specific regulations mandates off-site emergency planning.[23] There are a number of measures that applicants can use to demonstrate that their proposed facilities would remain under this dose limit. These design attributes are well established in the radioactive materials handling space and include:

- Facility design or engineered safety features, [24] such as:
  - setback from the site boundary line;
  - holding tritium systems at negative pressure in helium atmosphere glovebox enclosures; and
  - selection of appropriate materials and barriers.

- Physically separating radioactive material so that only a fraction of the inventory could be involved in an accident.[25]

Applying these mitigation measures to fusion system designs is consistent with NRC precedent and best practices in radioactive materials handling. Accordingly, the fusion energy machines under development by private enterprises, like CFS, differ significantly from fission reactors. The fusion systems that are under development in the U.S. fusion industry have smaller facility footprints, tritium inventories, and risk profiles compared with the international fusion experiments like ITER and DEMO.

As the next two sections demonstrate, a materials licensing approach, as under Parts 20 and 30 of NRC's regulations, is much more appropriate for commercial fusion systems compared with the utilization facility approach embodied by Parts 50 and 52.

III. Because Fusion Is Fundamentally Different from Fission, Regulating Fusion Energy Machines Under Parts 50 and 52 Is Not Appropriate

The statutory and regulatory framework for utilization facilities is designed for fission systems. Since fusion operations are fundamentally different from fission operations, commercial fusion systems cannot reasonably fit within the definition of a utilization facility.

A. Commercial Fusion Machines Do Not Fit Within the Definition of a Utilization Facility

The regulations surrounding utilization facilities were created and built out with fission operations in mind, not fusion. Under the AEA statutory scheme, the term "utilization facility" is defined as:

(1) Any equipment or device, except an atomic weapon, determined by rule of the Commission to be

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[23] 10 C.F.R. § 30.32(i)(1)(i). Absent this demonstration, applicants must provide an emergency plan to respond to such a release of material. *Id.*
[24] 10 C.F.R. § 30.32(i)(2)(v).
[25] 10 C.F.R. § 30.32(i)(2)(i).

i. 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

ii. 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.[26]

For a device to qualify as a utilization facility, it must squarely fall within this definition. Fusion energy systems do not use special nuclear material and,[27] even to the extent fusion energy systems are deemed to use "atomic energy,"[28] fusion still neither impacts the common defense nor negatively affects the health and safety of the public.[29] Fusion, therefore, does not fit into the statutory definition of "utilization facility."

NRC has implemented the AEA's definition of "utilization facility" in its Part 50 rules, defining it as:

(1) Any nuclear reactor other than one designed or used primarily for the formation of plutonium or U-233; or

(2) An accelerator-driven subcritical operating assembly used for the irradiation of materials containing special nuclear material and described in the application assigned docket number 50-608.

Fusion energy machines do not fit the regulatory definition of "nuclear reactor," and fusion energy machines neither irradiate materials containing special nuclear material nor are used for the specific applications outlined in docket number 50-608. For purposes of these regulations, "nuclear reactor" means an "apparatus, other than an atomic weapon, designed or used to sustain nuclear fission in a self-sustaining chain reaction."[30] As demonstrated in Section II.B above, no commercial fusion energy machines will employ a self-sustaining chain reaction. For the second part of this definition, NRC included the docket number with the objective of avoiding unintended consequences of the provision being applied to other applicants or licensees whose operations do not squarely fit into docket 50-608. The rule explicitly limits its application exclusively to irradiation units described in

[26] AEA Section 11(cc) (42 U.S.C. § 2014(cc)).
[27] Agreement States may regulate the use of some amounts of special nuclear material, just not large enough quantities of special nuclear material to form a critical mass. 42 U.S.C. § 2021(b)(3). For example, Massachusetts has delegated authority to regulate some quantities of special nuclear material. 62 Fed. Reg. at 16,629.
[28] "Atomic energy" is defined as "all forms of energy released in the course of nuclear fission or nuclear transformation." 42 U.S.C. § 2014(c).
[29] FIA White Paper at 13–14. See also Section VI below.
[30] 10 C.F.R. § 50.2.

docket 50-608.[31] Therefore, fusion energy machines fall outside out of the regulatory definition of "utilization facility."

B. Application of the Parts 50 and 52 Rules to Fusion Energy Systems Is Not Appropriate

In addition to the legal fact that fusion operations do not fit within either the statutory or regulatory definition of "utilization facility," the rules that apply to utilization facilities are not practically suited for application to fusion operations. There are differences between the scope of NRC's regulations in Part 30 and Parts 50 and 52. To the extent that the differences result in heightened regulatory attention for utilization facilities under Parts 50 and 52, is simply a product of Congress's and NRC's reasonable judgments as to the risks that the handling of byproduct material actually presents versus the risks posed by utilization facilities regulated pursuant to Parts 50 and 52.[32]

For example, the Price-Anderson Nuclear Industries Indemnity Act ("Price-Anderson Act") mandates that commercial licenses for utilization facilities require that, as a condition of the license, the licensee maintain financial protection in an amount required by the NRC to cover public liability claims and maintain an indemnification with the NRC for these risks.[33] Congress created the Price-Anderson Act to address liabilities from risks inherent to nuclear fission accidents, particularly offsite radiological injury to the public. But these safety risks do not apply to fusion operations, so the financial protections from the Price-Anderson Act would not apply to a fusion energy system operator. It would be unreasonable to require the future fusion energy industry to be financially responsible for accidents in the fission industry.

Additionally, utilization facilities have unique rules surrounding their relationship to the international stage. For example, utilization facilities are prohibited from being foreign owned.[34] If inappropriately applied, this restriction could impact market development and deployment of fusion energy systems in the United States since many fusion developers have attracted interest from investors outside the United States, and that number is only likely to rise. Also, if fusion energy systems are regulated as utilization facilities, then the NRC's more extensive export licensing requirements for utilization facilities[35] will apply. Given that fusion has historically been, and continues

[31] The rule that added this language to the regulations was intended to "only affect[] the irradiation units proposed by SHINE under docket number 50-608." 79 Fed. Reg. 62,333 (Oct. 17, 2014); *see also* Office of Nuclear Reactor Regulation Response to Request Regarding the Applicability of the Definition of Utilization Facility to the Demonstration Unit of SHINE Medical Technologies, Inc. ADAMS Accession No. ML17142A433.

[32] For example, Part 37 covers the physical protection of category 1 and 2 quantities of radioactive materials from theft or diversion. 10 C.F.R. § 37, Appendix A. Tritium is not covered by that rule, but there is a separate rule within Part 30 specifically governing the reporting requirements of theft or diversion of tritium above a certain quantity threshold. 10 C.F.R. § 30.55. By creating a separate reporting rule for theft and diversion of tritium, NRC suggests that tritium is not necessarily as high of a concern as the substances enumerated in Part 37 and, more importantly, that NRC has already narrowly tailored the tritium reporting rule to be commensurate with its specific risks. Additionally, non-radioactive substances used in fusion, like deuterium, do not hold the same risks in use and therefore do not need to have such rules apply to them.

[33] 42 U.S.C. § 2210(a)–(c).

[34] 42 U.S.C. § 2133(d); *see also id.* § 2134(d).

[35] 10 C.F.R. § 110.42.

to be, a very global industry with technical expertise located throughout the world. Since private fusion companies seek to deploy their energy solutions globally to address climate change, this restriction produces no benefit to U.S. national security and would likely drive private fusion companies to develop their technologies outside the United States.

Finally, the AEA prohibits the delegation of regulatory authority from the NRC to Agreement States regarding the construction and operation of any production or utilization facilities.[36] Thus, at best regulating fusion operations under Parts 50 and 52 would be redundant to the regulatory role that Agreement States already play to ensure safe fusion operations and at worst, because there is no reason to treat byproduct material used or created in fusion energy machines differently from other byproduct material, dismantling the Agreement State program for byproduct material.

C. Fusion Energy Machines Are Not Significant to the Common Defense and Security

Fusion energy machines will not be of significance to the common defense and security as referenced in the definition of "utilization facility." No fusion energy machine will use, manufacture, produce, or handle any special nuclear material or source material. As they are being designed, fusion energy machines will not be capable of producing fissionable materials.

In order to manufacture weapons materials, a fusion energy machine would have to be completely deconstructed and re-designed. Even if some of the parts from the original fusion energy machine were used to manufacture such materials, the resulting reconstituted apparatus would bear little practical resemblance to any commercial fusion energy machine. At a high level, the re-design would have to include the following:

- Access to either special nuclear material or source material in violation of the safeguards regime;
- Fusion neutrons are born at 14.1 MeV where the fission cross section for U-238 is hundreds to thousands of times more likely than capture, therefore a specially designed neutron moderator would need to be created and installed within the fusion energy machine;
- The fertile material would have to be encapsulated in several layers of some inert material like graphite to avoid the fertile material from being dissolved into the liquid blanket and causing operational issues with the blanket purification systems which are not designed to handle fission products nor solid chunks of encapsulated fertile material;
- A specially designed apparatus would need to be installed to remove the highly irradiated fertile material from the blanket and transport it to a separate reprocessing facility that would separate fission fragment isotopes from the bred special nuclear material; and
- Performance penalties that are a result of an interruption of normal operation would need to be addressed. The fusion energy facility would likely not be capable of generating enough tritium to maintain power operation since the fission fragment isotopes would parasitically absorb neutrons that were meant to regenerate tritium. Thermal loads in the blanket would also increase and therefore design safety

[36] 42 U.S.C. § 2021(c)(1).

margins in structural components would be decreased. The structural integrity of the facility would then be called into question.

As a result, it is impossible for fusion energy machines to produce fissionable materials, absent extreme misuse or abuse of this technology. The potential proliferation risk for such abuse is addressed by the U.S. Department of Commerce's dual-use regulations in the Export Administration Regulations.[37] There is no regulatory gap that NRC needs to expand its jurisdiction to fill in order to address potential proliferation risks.

Furthermore, consumable inputs for fusion energy machines, such as tritium to assist in the start-up of a deuterium-lithium fueled facility like future ARCs, are all available on the commercial market.[38] There would be no diversion of materials like tritium from national defense or security uses.

CFS is also aware of interest regarding the use and availability of lithium-6 for use in blanket systems to generate tritium. Although not widely appreciated, lithium-7 may also be used in a blanket to generate tritium. In fact, CFS is working with MIT on a project funded by ARPA-E to demonstrate the technology underpinning the commercial use of naturally occurring lithium (~92.5% Lithium-7 and ~7.5% Lithium-6), not only lithium-6, to regenerate tritium for use in future fusion energy machines.

IV. A Materials Licensing Approach to Regulating Fusion Under Parts 20 and 30 Fully Captures Current and Foreseeable Developments Within the U.S. Commercial Fusion Sector

Because the materials licensing regulations described in Parts 20 and 30, as implemented by NRC and Agreement States, appropriately address the risks that fusion energy systems present, the Commission and Agreement States have regulated devices that use fusion reactions for many years without issue. The fusion industry has already explained in summary form why Parts 20 and 30 adequately regulate fusion energy machines.[39] However, this submission elaborates on how and why Parts 20 and 30 already adequately address the commercial fusion systems anticipated in the United States.

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[37] 15 C.F.R. Part 774 Supplement No. 1 at, e.g., ECCNs 1B999, 3A101, and 3A201.

[38] In the event that the global tritium market tightens in the future, CFS plans to be fully self-sufficient on tritium supplies for future power plant fleet growth.

[39] FIA White Paper; *see also* PowerPoint Presentations from Virtual Public Meeting on Developing Options for a Regulatory Framework for Fusion Energy Systems (Mar. 30, 2021).

A. Part 20 Comprehensively Regulates the Low-Level Waste Generated by Fusion

As explained above, Part 20 already regulates the disposal of the low-level waste that is generated from fusion operations.[40] Because fusion operations do not generate high-level waste, Part 20 is an appropriate framework through which to control the disposal of such low-level operational waste. Asserting exclusive federal jurisdiction for the regulation of this low-level waste produced by fusion energy systems would also upend the Agreement States' agreements, which already cover the types of wastes that fusion energy systems would generate which is low-level activated waste. Therefore, Part 20 sufficiently addresses the waste associated with commercial fusion energy systems.

B. Tritium Fits Within the Byproduct Material that Part 30 and Agreement States Regulate

Part 30 regulates domestic licensing of byproduct material under the AEA, which includes all tritium available on the commercial market. Currently, tritium that is used in fusion energy systems can be sourced externally from CANDU nuclear reactors that use special nuclear material which then produce tritium, thereby fitting tritium into subpart (1) of the definition of "byproduct material."[41] Future commercial fusion energy systems will generate their own tritium on site (likely using molten salt blankets), which can be regulated similarly to existing byproduct material under Part 30.[42] But current fusion energy systems using tritium fuel cycles already fall within the AEA's and the Commission's definition of "byproduct material."

To date, NRC has delegated authority to 39 states who have since entered into the Agreement State Program to regulate radioactive materials and sources under Part 30.[43] These Agreement States collectively oversee 17,000 radioactive material licenses, which represent roughly 86 percent of all byproduct material licenses in the United States. For example, the State of Wisconsin already has regulatory authority over the SHINE Technologies, LLC neutron fusion generator technology, which uses both deuterium-deuterium[44] and deuterium-tritium fusion reactions to produce neutrons for medical treatment and industrial uses.[45] The reaction created in the SHINE device is the same as many other commercial fusion applications.[46] Additionally, New York also already has regulatory authority over a scientific research facility conducting laser-induced fusion and inertial confinement fusion called "OMEGA" located at the University of Rochester's Brighton campus.[47] OMEGA has operated since 1970. For this reason, regulating fusion energy through a means other than via its byproduct material program would ignore Agreement States' preexisting roles in regulating fusion operations to date.

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[40] 10 C.F.R. §§ 30.31, .32(i)(1)–(2), 20.2001 (disposal requirements for waste), 1003 (defining "waste" as low-level waste).

[41] 10 C.F.R. § 30.4.

[42] NRC's regulatory authority may need to evolve with the industry in order for regulations to maintain comprehensive oversight over fusion materials, as outlined below. Any actions taken to clarify NRC's regulatory authority would be organic progressions of the current Part 30 regime in line with fusion industry growth.

[43] FIA White Paper at 3, 15.

[44] *See, e.g.*, 10 C.F.R. §§ 30.14 (exempt concentrations), .31, .32(i)(1)–(2), .70 Schedule A (exempt concentrations).

[45] FIA White Paper at 3; *see also* NEUTRON GENERATORS, PHOENIX, LLC, https://phoenixwi.com/neutron-generators/.

[46] FIA White Paper at 17.

[47] LLE SAFETY ZONE, LABORATORY FOR LASER ENERGETICS, https://www.lle.rochester.edu/index.php/safety/radiological-safety/.

Finally, and most importantly, state agencies regulate and license particle accelerators themselves.[48] Any newly asserted NRC authority over accelerators, like fusion energy machines, would conflate the current regulation of accelerator devices with the byproduct material that NRC (or Agreement States) actually regulates. CFS is concerned that such an approach would impose unnecessary and inefficient regulatory burdens on fusion energy machines, which is not warranted by the risks that such material or machines present.

C. Current Graduated Requirements under Part 30 Satisfy Congress's Mandate for Risk-Informed Framework

NRC has already created a graduated approach for regulating byproduct material pursuant to Part 30, adequately capturing Congress's mandate for a risk-informed framework for the array of foreseeable commercial fusion operations that are expected to take place.[49] This approach calibrates regulatory scrutiny with the risks posed by the licensed material handling. Part 30's existing framework on this point does not differentiate between projects that are physically "large" or "small"; such subjective characteristics should not dictate the level of regulatory analysis. Any risk that a fusion energy machine could pose will not turn on the size of its geographic footprint or its eventual power output, but rather on its fuel selection, radioactive material inventory, and quantity of activated low-level waste generated by the operations. Importantly, CFS believes that power output is not a useful metric for establishing regulatory processes for fusion energy. Although in the fission context power output is directly proportional to the special nuclear material present in the fission reactor as fuel, no such relationship exists between fuel volume and power output exists in the fusion context.

Underscoring the importance of these particular characteristics, Part 30 imposes different levels of requirements on different quantities of byproduct material, including:

- Exempts certain small quantities and concentrations of byproduct material from regulation, recognizing the very low risk that such concentrations of material would create.[50] NRC has removed regulation over certain concentrations of tritium under this framework.

- Excludes from regulation those people that receive, possess, use, or own consumer products that contain certain small amounts of byproduct material that is otherwise regulated at a different point in the chain of that product's life cycle.[51]

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[48] *See, e.g.*, 105 Mass. Code Regs. § 120.700.

[49] CFS is aware of a letter that Helion Energy, Inc. ("Helion") submitted to the Commission in March 2021 wherein Helion suggests that NRC develop a completely new "graded approach" for fusion energy devices. Letter from D. Kirtley, Helion Energy, Inc., to W. Reckley, NRC, ADAMS Accession No. ML21085A477 (Mar. 25, 2021). This approach is not consistent with FIA's consensus position of the private fusion industry, and CFS does not believe that fusion energy machines warrant a new approach that is distinct from the existing Parts 20 and 30 materials licensing framework.

[50] 10 C.F.R. §§ 30.14 (exempt concentrations), .18, .70 Schedule A (exempt concentrations).

[51] 10 C.F.R. §§ 30.15 (certain items containing byproduct material), .19 (self-luminous products containing tritium), .20 (gas and aerosol detectors containing byproduct material).

- Provides for specific versus general licensing of byproduct material, including a specific license for byproduct material.[52]

- Requires an emergency plan for inventories of radioactive material in certain quantities.[53]

- Applies the physical protection requirements for theft and diversion under Part 37 for certain quantities of radioactive material that are considered byproduct material.[54]

- Includes scaled emergency reporting requirements for certain events involving specific quantities of licensed material.[55]

- Requires demonstration of financial assurance for decommissioning of facilities handling certain quantities of byproduct material.[56]

- Allows low concentrations of tritium in liquid scintillation media to be disposed of as if they are not radioactive.[57]

These provisions of Part 30 calibrate regulatory oversight to hazards that byproduct material used or created by fusion energy machines, all in accordance with NEIMA's mandate. Accordingly, there is no need for NRC to regulate fusion energy systems otherwise.

D. Part 30 Already Contains Provisions that Comprehensively Regulate the Handling of Byproduct Material—Like Tritium—Throughout the Byproduct Handling Life Cycle

Part 30 also ensures the safety of fusion operations during the entire life cycle for byproduct materials handling:

- General requirements, terms and conditions of licenses, and particularly specific licenses regulated under Part 30, include requirements to demonstrate off-site impacts in case of a release of radioactive material, will not exceed a certain maximum dose quantity to an off-site person, in addition to rules on transferring or assigning a license.[58]

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[52] 10 C.F.R. §§ 30.31, .33.
[53] 10 C.F.R. §§ 30.32(i)(1)–(2), .72 Schedule C.
[54] None of the radioactive materials listed in Appendix A to 10 C.F.R. Part 37 would be present at a private fusion facility, and tritium already has its own reporting rule for theft and diversion under 10 C.F.R. § 30.55.
[55] 10 C.F.R. § 30.50(b)(4).
[56] 10 C.F.R. §§ 30.32(h), .35.
[57] 10 C.F.R. § 20.2005(a).
[58] 10 CFR §§ 30.32(i)(1)–(2), .33, .34(b).

- National Environmental Policy Act compliance requirements for the receipt and possession of byproduct material for any activity deemed by NRC to significantly affect the quality of the environment.[59]

- Requirements for reporting, inspecting, recording, and testing, including specific reporting for theft and diversion of tritium.[60]

- Rules for deliberate misconduct that violates byproduct licensing regulations.[61]

- Rules on mandated modification or revocation of licenses for failing to observe any requirement of the AEA or for providing material false statements in a license application.[62]

- Rules mandating the withholding or recalling of byproduct material for failure to either observe safety standards or otherwise use the material in violation of the AEA or otherwise in contravention with the stated purpose in the license application.[63]

- Sanctions for violations of the AEA, including either an injunction or court order for a civil breaches,[64] or criminal penalties for violations issued under a majority of the regulations of Part 20 and 30 of the NRC's regulations.[65]

With this structure in place, Part 30 already fully addresses the risks that byproduct materials—including tritium and activated materials—used in fusion energy systems like SPARC and ARC could present. Recreating a life cycle regulatory regime for fusion based on a specific device, nuclear reaction, or other subjective criterion will be an unnecessary expenditure of resources and a misdirected use of time when the real risk created by fusion, if any, is born out of the material used and not by the devices themselves.

V. Enabling Fusion's Evolution via a Materials License Program

CFS expects that regulatory flexibility will be crucial to fostering an innovative and competitive fusion energy industry in the United States. The Part 30 byproduct materials licensing framework embodies this flexibility.

A. Existing Regulations and Guidance Documents Are Well Suited to Regulate Fusion Today

Based on its interactions with both state and federal regulators, CFS believes that the existing regulations, including regulations adopted by Agreement States, adequately address the hazards associated with any fusion energy machine likely to be proposed in the foreseeable future. Existing guidance documents, particularly NUREG

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[59] 10 CFR §§ 30.32(f), 51.60. See below for additional discussion of environmental review applicable to fusion energy projects.
[60] 10 C.F.R. §§ 30.50–.55.
[61] 10 C.F.R § 30.10; *see also id.* § 2.200–.206 (enforcement).
[62] 42 U.S.C. § 2232 (Section 182 of AEA); *see also* 10 C.F.R. § 30.61.
[63] 10 C.F.R. § 30.62.
[64] 10 CFR §§ 20.2401(a)(3), 30.63(a)(3).
[65] 10 CFR §§ 20.2402, 30.64.

1556 Volume 21, is the appropriate regulatory supplement to answer regulators' questions about approaching specific issues in an application related to material in or inadvertently created by a fusion energy machine. And once the regulator's analysis is complete, the specific licensing process in Part 32 of the Commission's regulations provides a well-understood process for addressing project-specific issues.

Over time, as regulators, the regulated community, and all other stakeholders develop experience with fusion energy machines, it may become appropriate to update these guidance materials. NRC could add a fusion-focused appendix to NUREG 1556 Volume 21 to address questions that have emerged from the operational experience gained to date. And eventually it may become efficient to create a new NUREG, likely in the 1556 series, for fusion energy machines that would streamline licensing approvals. The NUREG process is more flexible than adjusting formal regulations and can accommodate rapidly advancing technologies like fusion energy more readily than formal regulations.

B. Fusion Energy Is Not Mature Enough to Warrant a Separate Part in the NRC's Regulations

Fusion energy is not the first new technology to approach the commercial market since NRC's inception. The agency's approach to both irradiators and well loggers can be instructive examples for the fusion energy sector. In each instance, state and federal regulators, and regulators around the world, developed experience with these devices for decades before initiating a rulemaking process for these technologies.

In 1990, NRC staff undertook a rulemaking for irradiators that eventually became 10 C.F.R. Part 36.[66] Providing the foundation for this new rule, the Commission summarized numerous lessons learned from the prior decade-plus of regulating irradiators in concord with the Occupational Safety and Health Administration and states.[67] This catalogue of anecdotal incidents illustrates the substantial operating experience that industry and regulators had developed before NRC attempted to standardize its regulatory processes via a formal rulemaking.

Similarly, in the 1980s NRC attempted to standardize licensing of material used in well logging. By the agency's calculation, the regulated community was engaging in 90,000 well logging actions per year in 1987.[68] All of this activity, following decades of well logging regulation on case-by-case bases, indicates a wealth of experience that informed the rulemaking process.

There is no comparable track record for fusion energy machines to draw from in order to develop a separate rulemaking for fusion energy machines at this point. Even attempting to adapt portions of existing rules to fusion energy machines in formal regulations does little to effect the goals of streamlining and clarifying licensing activities. Absent the experience gained from multiple development, operational, and maintenance cycles from multiple fusion energy machines, a process to develop regulations now for the complete universe of fusion energy technologies is not an efficient use of administrative resources because that effort will not be informed by practical experience.

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[66] NRC, Licenses and Radiation Safety for Large Irradiators, 55 Fed. Reg. 50,008 (Dec. 4, 1990).
[67] 55 Fed. Reg. at 50,010-13.
[68] NRC, Licenses and Radiation Safety Requirements for Well Logging, 52 Fed. Reg. 8,225 at 8,226.

In both of the above technology-specific rulemakings, NRC highlighted the potential benefits in administrative efficiency that broader rulemakings would provide to regulators.[69] CFS agrees that administrative efficiency is an important consideration. Regulators, including NRC and across the Agreement States, can achieve these efficiencies via guidance documents at this point rather than formal rulemaking.

CFS recognizes that at some point in the future, following numerous operational cycles for multiple fusion energy machines, perhaps the goals of regulatory efficiency and clarity that prompted the new rules for irradiators and well loggers could point to more specific guidance for fusion energy. But today, maintaining the current Parts 20 and 30 regulations and relying on existing guidance documents (as may be supplemented to keep current with the developing industry) is the best way to advance these regulatory objectives.

C. NRC has Discretion to Resolve Potential Confusion in the Materials Licensing Program

CFS appreciates that there could be some confusion in the current format and wording of the regulations in Parts 20 and 30. In particular, it has been suggested that the wording of the AEA and the agency's implementing regulations to define byproduct material as created by operation of a particle accelerator may not fully cover activated material, like tritium that is created and used on site to catalyze fusion reactions between the deuterium and lithium fuel, or any other activated waste material.[70] To address this potential confusion and clarify the agency's intent, CFS suggests very minor changes to Parts 20 and 30, such as defining a fusion energy machine as a particle accelerator, to ensure that regulators, the regulated community, and all stakeholders understand that radionuclides used in and created by fusion energy machines are regulated within the materials licensing framework. It is important to note that clearing up this definitional confusion does not alter the existing reality that tritium generated in fusion research machines, such as via the deuterium-deuterium reaction, is already regulated pursuant to Part 30 and Agreement States.

When considering this question, it is important to highlight the broad discretion that Congress has granted to the Commission to define "particle accelerator.[71]" Although Congress directed NRC to regulate material activated by particle accelerators as byproduct material, Congress did not define "particle accelerator" in the statute and has not defined the term in any other context in the U.S. Code. Congress, therefore, has left it to the Commission to define the term. The NRC did so in a rule finalized in 2007.[72]

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[69] *See* 55 Fed. Reg. at 50,010 (suggesting that a formal rule could allow NRC to license irradiators with fewer conditions and streamline the inspection process); 50 Fed. Reg. at 13,798 (hypothesizing that a formal rule would clarify licensing standards for well logging activities because licenses were issued by NRC regional offices, not headquarters).

[70] David R. Lewis, Jeffrey S. Merrifield, and Sidney L. Fowler, Considerations in the Regulation of Fusion-Based Power Generation Devices at 3 (Nov. 19, 2020), https://www.pillsburylaw.com/images/content/1/4/v8/144195/Article-Licensing-Fusion-Power-Nov2020.pdf.

[71] FIA's recent presentation to NRC staff outlines the legal precedent underpinning NRC's broad statutory discretion in regulatory matters. See *FIA Presentation on Developing a Regulatory Framework for Fusion Energy Systems* at 36 (June 7, 2022), http://www.nrc.gov/docs/ML2215/ML22159A269.pdf (pointing to *Siegel v. Atomic Energy Comm'n,* 400 F.2d 778, 783 (D.C. Cir. 1968)."

[72] Requirements for Expanded Definition of Byproduct Material, 72 Fed. Reg. 55,864 (Oct. 1, 2007)

When NRC promulgated its rule to implement Congress's directive on particle accelerators, the Commission indicated its intent that material like tritium created and consumed on site, saying that "[i]f a neutron generated by the accelerator is used to produce radioactive material via neutron activation, and the resulting radioactive material is used for a commercial, medical, or research activity, the radioactive material (and any incidentally produced radioactive material), would be regulated as byproduct material under Section 11e.(3) of the AEA as amended."[73] Because fusion machines fit the definition of "accelerators" and are considered neutron generators, such as in the case of the neutron-generator portion of SHINE medical isotope production system, it follows that NRC intended and the Part 30 materials program logically should fully regulate the activated material produced intentionally or incidentally by the a fusion energy machine.

All fusion energy machines fit within the category of particle accelerators.[74] In the case of a tokamak machine capturing energy from deuterium and tritium fusion reactions, the tokamak machine accelerates, or heats, the deuterons and tritons in a vacuum to approximately 100 million degrees Celsius.[75] Following fusion, in a fusion energy machine the resulting particulates of a helium atom and a neutron carry 3.5 megaelectron volts and 14.1 megaelectron volts respectively into the so-called "blanket," a medium that will be used to entrain neutrons for creation of more tritium catalyst and capture heat for heat exchange and eventual power generation in the balance of plant. As noted during the NRC's public meeting on June 7, 2022, CFS is not aware of any fusion energy machine being developed by a private company that would not meet this criteria.[76]

However, to the extent that the Commission believes that its materials licensing program could be improved by clarifying its regulations to remove this confusion, CFS suggests that explicitly placing "fusion energy machines" within the "particle accelerator" paradigm may simply and directly address this issue. Formally characterizing fusion energy machines as particle accelerators resolves any residual confusion on this front. One way to accomplish this clarification is by adding the following definition to Parts 20 and 30 of the Commission's regulations:

> *Fusion energy machine* means a machine in which charged particles are accelerated in order to create conditions conducive to fusion reactions and in which the products of such reactions

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[73] 72 Fed. Reg. at 55,896.

[74] The Commission's regulations define "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." 10 C.F.R. § 30.4. *See also* 10 C.F.R. § 20.1003 (providing an equivalent definition in Part 20 of the regulations).

[75] Heating these hydrogen isotopes to 100 million degrees Celsius is equivalent to accelerating each hydrogen atom to approximately 10 kiloelectron volts.

[76] CFS also notes that some existing particle accelerators may be entering the energy space as well. The Large Hadron Collider (LHC) in Europe, arguably the most famous particle accelerator in the world, has established a pilot program to put some of its waste heat into the local heating market. Michael Irving, *The Large Hardon Collider Will Soon Help Heat Nearby Homes*, NEW ATLAS (July 25, 2019), https://newatlas.com/cern-large-hadron-collider-heat-homes/60724/. Although the LHC's waste heat is not from particle collision but rather from ancillary systems, it is clear that particle accelerators can be put to evolving uses, even energy missions like fusion energy machines.

(including heat or other electromagnetic radiation) are captured for the purpose of generating net positive energy. Fusion energy machines are deemed to be particle accelerators.

Lastly, NRC has exercised this discretion before when it defined "cyclotron" to be a particle accelerator in its Part 30 rules. When Congress directed NRC to assume regulatory authority over substances activated by particle accelerators, nowhere did Congress mention the term "cyclotron."[77] NRC used its discretion to bring cyclotrons into the explicit ambit of "particle accelerator" for purposes of the materials licensing program.[78] Similarly, NRC could use its discretion to state clearly that fusion energy machines are deemed to be particle accelerators as defined by the Commission and, therefore, definitively within the materials licensing program.

D. Legislative Action Is Not Necessary at this Time

CFS agrees with the presentation offered by the FIA to NRC's public meeting on June 7, 2022, particularly that the AEA empowers NRC with sufficient discretion to regulate material activated by and handled with fusion energy machines.[79] CFS is not opposed to updating federal statutes to keep pace with developments in the fusion energy sector and the minor legislative changes to the AEA that the FIA has proposed are an elegant way to provide additional regulatory clarity to all stakeholders while maintaining the byproduct material approach for fusion energy. However, CFS is concerned that if NRC waits for Congress to provide further direction on this point instead of using its statutory discretion, the United States could lose its chance to cement its place as a leader in commercial fusion energy.

CFS encourages NRC and other US policymakers to consider the example of fusion regulation in the United Kingdom. There, the UK Government proposed a materials licensing approach for fusion energy and solicited public input.[80] Following this extensive public engagement, the Government adopted a general materials licensing framework for commercial fusion energy.[81] To solidify its approach, the Government indicated that it will enroll into statute a "new pro-innovation regulatory environment for fusion energy."[82] In the UK, legislators are following the lead of the regulatory expert agencies and plan to codify the approach that the regulators recommend. If NRC determines that a Part 30 materials licensing approach is appropriate, CFS would not object to Congress codifying

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[77] Energy Policy Act of 2005, Pub. L. No. 109-58, § 651(e), 119 Stat. 594, 807 (2005).

[78] In finalizing its rule for particle accelerators, NRC referred to two types of accelerators: "linear and circular, also known as cyclotron." 72 Fed. at 55,868.

[79] Presentation by Andrew Holland of the Fusion Industry Association at pp. 35-40, ML22159A269 (June 7, 2022).

[80] Towards Fusion Energy: The UK Government's Proposals for a Regulatory Framework for Fusion Energy, DEP'T FOR BUSINESS, ENERGY & INDUS. STRATEGY (Oct. 2021), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1032848/towards-fusion-energy-uk-government-proposals-regulatory-framework-fusion-energy.pdf.

[81] Towards Fusion Energy: The UK Government's Response to the Consultation on Its Proposals for a Regulatory Framework for Fusion Energy, DEP'T FOR BUSINESS, ENERGY & INDUS. STRATEGY (June 2022), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1084472/towards-fusion-energy-uk-government-response.pdf.

[82] The Queen's Speech 2022 at 33, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1074113/Lobby_Pack_10_May_2022.pdf (May 10, 2022) (describing the contents of a planned Energy Security Bill).

this approach via minor adjustment to federal statute and looks forward to working with all stakeholders to effect such updates.

VI. Conclusion

NRC's existing approaches in its regulatory programs under Parts 20 and 30 of the Commission's regulations will adequately address the risks that fusion energy systems would present. Imposing the rules of Parts 50 and 52 on fusion energy systems will create administrative inefficiencies, excessive regulatory burdens and will not further NRC's mission to "provide reasonable assurance of adequate protection of public health and safety and to promote the common defense and security and to protect the environment." As demonstrated above, SPARC and ARC fit well within NRC's materials licensing program, and CFS sees no reason why development of a Part 53 or some other fusion-specific framework should replace the current regulatory approach that already works for fusion energy systems under Part 20 and 30.

Thank you for your consideration of these issues, which are critical to the development of and deployment of fusion energy technologies in the United States. We look forward to a continued dialogue with the NRC and its Commissioners.

Sincerely,

Tyler Ellis, Ph.D.

Commonwealth Fusion Systems LLC

CC: Commissioner Jeff Baran, NRC

Commissioner Annie Caputo, NRC

Commissioner David A. Wright, NRC

Daniel H. Dorman, Executive Director for Operations, NRC

Marian Zobler, General Counsel, NRC

Catherine Haney, Deputy Executive Director, NRC

Darrell Roberts, Deputy Executive Director, NRC

John Lubinski, Director of Office of Nuclear Materials Safety and Safeguards, NRC

Andrea D. Veil, Director of Nuclear Reactor Regulations, NRC

Andrew Proffitt, Coordinator of Fusion Energy Working Group, NRC

From: Tyler Ellis <tyler@cfs.energy>
Sent: Wednesday, August 17, 2022 3:45 PM
To: CMRHanson Resource
Cc: CMRBARAN Resource; CMRCaputo Resource; CMRWright Resource; Daniel.Dorman@nrc.gov; Zobler, Marian; Haney, Catherine; Roberts, Darrell; Lubinski, John; Veil, Andrea; Proffitt, Andrew
Subject: [External_Sender] CFS letter for NRC
Attachments: CFS - NRC Submission Final.pdf

Dear Chairman Hanson,

We've pulled together a letter that covers some additional thoughts on several topics which have come up over the past few NRC public meetings on fusion energy that will hopefully be helpful for both the Commission and the NRC staff working on the fusion regulatory paper. It's fine for this to be publicly available and put up on the NRC Fusion Energy website, if you wish.

If you and anyone else interested are available, I'm happy to stop by the NRC to provide a high-level overview of the letter as well as share updated construction progress pictures from the SPARC site.

Thanks,
Tyler