NRC Staff Prepared White Paper
"Licensing and Regulating Fusion Energy Systems"
September 2022 Draft – Released to Support ACRS Interaction

THIS NRC STAFF WHITE PAPER HAS BEEN PREPARED AND IS BEING RELEASED TO SUPPORT INTERACTIONS WITH THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS). THIS PAPER HAS NOT BEEN SUBJECT TO NRC MANAGEMENT AND LEGAL REVIEWS AND APPROVALS, AND ITS CONTENTS SHOULD NOT BE INTERPRETED AS OFFICIAL AGENCY POSITIONS.

SUBJECT: Licensing and Regulating Fusion Energy Systems

PURPOSE:

The purpose of this paper is to support upcoming interactions with the Advisory Committee on Reactor Safeguards on options for licensing and regulating fusion energy systems.

BACKGROUND:

There are many commercial companies[1] world-wide developing fusion technology using a wide variety of fusion concepts and fuel cycles with the goal of producing electricity. The state of the science, technological breakthroughs, and component manufacturing improvements have led several companies to expect proof of concept of their designs in the mid to late 2020s, including net power production (e.g., Q>1). Many are targeting the 2030s for commercial deployment. This is consistent with the U.S. Department of Energy's "Bold Decadal Vision for Commercial Fusion Energy[2]." These commercial fusion companies have expressed a need for greater regulatory certainty to support their goals.

In Staff Requirements Memorandum (SRM)-SECY-09-0064, "Staff Requirements—SECY-09-0064—Regulation of Fusion-Based Power Generation Devices," dated July 16, 2009 (ADAMS Accession No. ML092230198), the Commission asserted, as a general matter, that "*the NRC has regulatory jurisdiction over commercial fusion energy devices whenever such devices are of significance to the common defense and security, or could affect the health and safety of the public*." Along with this assertion, the Commission directed the staff to wait until commercial deployment of fusion technology became more predictable before expending significant resources to develop a regulatory framework for fusion technology.

The Nuclear Energy Innovation and Modernization Act (NEIMA; Public Law 115-439), directs the NRC to develop the regulatory infrastructure to support the development and commercialization of advanced nuclear reactors. NEIMA's definition of an advanced nuclear reactor includes both fission and fusion technologies. Section 103 of NEIMA specifically requires the NRC to "complete a rulemaking to establish a technology-inclusive, regulatory framework for optional use by commercial advanced nuclear reactor applicants for new reactor license applications" by December 31, 2027.

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[1] See Fusion Industry Association's report "The Global Fusion Industry in 2022" https://www.fusionindustryassociation.org/about-fusion-industry
[2] See 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/

In SRM-SECY-20-0032, "Staff Requirements—SECY-20-0032—Rulemaking Plan on 'Risk--Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors (RIN-3150-AK31; NRC-2019-0062),'" dated October 2, 2020 (ADAMS Accession No. ML20276A293), the Commission directed the staff to "*consider appropriate treatment of fusion reactor designs in our regulatory structure by developing options for Commission consideration on licensing and regulating fusion energy systems*." In its response to the SRM dated November 2, 2020 (ADAMS Accession No. ML20288A251), the staff stated that the assessments of the potential risks posed by fusion technologies and possible regulatory approaches would be done in parallel with the development of the draft proposed rulemaking package for 10 CFR Part 53.

DISCUSSION:

Technical Assessment of Fusion Technologies

Nuclear fusion is a process where two, or more, atomic nuclei are combined to form a heavier element. This reaction releases excess energy and is the source of light and heat emitted by the sun. There are three general confinement approaches to producing energy from fusion: magnetic, magneto-inertial, and inertial. These methods generally seek to create an environment with sufficient density, temperature, and energy confinement time conducive to the fusion process. While uncertainties exist on the development of fusion energy systems, there have been recent technological breakthroughs that support the potential deployment of fusion power plants in the 2030s.

Important differences exist between fusion and fission. Fusion reactions involve no special nuclear material (i.e., plutonium, uranium-233, or uranium enriched in the isotope-233 or in the isotope-235), and a self-sustained chain reaction is not possible. Therefore, the radiological hazards associated with the technology are comparatively much lower than those for the large light water fission reactors in operation today.

The main radiological hazards from a fusion energy system are driven by the inventories of radioactive material at the site and the radiation produced during operation. Confinement of these materials (e.g., tritium and activated materials) and shielding of the radiation (e.g., gamma and neutron) are the main areas of focus for protecting public health and safety. Additional information on the fusion process and associated hazards is provided in the UK Atomic Energy Authority's "Technology Report – Safety and Waste Aspects for Fusion Power Plants," September 2021[3].

The staff has assessed potential risks from various fusion energy systems and engaged subject matter experts from the Department of Energy (DOE), national laboratories, international organizations, developers, and other organizations and individuals. Examples of the risks posed by fusion energy systems:

- In the event of a vessel breach in a fusion device, there are no sustained fusion reactions because a vacuum is physically needed for the plasma to be heated and confined (in which the fusion reaction occurs).

[3] The report can be found at: https://scientific-publications.ukaea.uk/wp-content/uploads/UKAEA-RE2101-Fusion-Technology-Report-Issue-1.pdf

- Some studies indicate that even in the case of a total loss of active cooling, the low residual heating excludes melting of the device's structures[4].
- Because the vessel is in a vacuum, it is anticipated that air would enter at a faster rate than the diffusion of tritium out of the device, thus minimizing any initial release[5].
- The tritium processing and handling systems will process and may contain large quantities of tritium.
- Radioactive releases and risk levels (without protective actions for nearby populations) are generally agreed to be lower for fusion devices than current generation fission-based power stations.
- Fusion devices will not produce any long-lived, highly radioactive waste that needs to be cooled before moving into a repository for disposition. In general, the majority of the waste output from a fusion facility should consist of low-level radioactive waste.
- Currently, developers are planning fusion devices without the use of any SNM or source material. Any proposed fusion-fission hybrid designs would be treated in the regulations like advanced fission reactors.

The staff reviewed DOE guidance for existing fusion research facilities in the U.S., safety reports for the International Thermonuclear Experimental Reactor (ITER), and received information from current developers. A common issue in assessing what risks are posed by fusion energy systems is that the risks are expected to vary depending on the specific fusion technology and design, the presence or absence of supporting systems for breeding tritium, and the inventories of tritium or other radionuclides at a potential site. However, when considering the potential for exposing members of the general public and workers at the sites to various types of radiation, the staff concludes that, while the risks are lower than for fission technologies, there is potential to affect the public health and safety for all the commercial fusion energy systems known at this time. The additional risks to the general public from system upsets for the technologies and designs assessed are expected to range from negligible to the risk associated with a fraction of current occupational exposure limits in 10 CFR Part 20.

<u>Regulatory and Legal Overview</u>

In SECY-09-0064 the staff began the analysis of determining if fusion energy systems could logically be considered either utilization facilities or particle accelerators and regulated under NRC's materials licensing program. The staff have performed further regulatory and legal analysis as follows.

Classification of Fusion Energy Systems as Utilization Facilities

Section 11cc. of the AEA defines utilization facility as follows (emphasis added):

> *The term "utilization facility" means (1) any equipment or device, except an atomic weapon, determined by rule of the Commission to be capable of making use of special nuclear material in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public, or peculiarly adapted for making use of atomic energy in such quantity as to be of significance to the common defense and security, or in*

[4] European Safety and Environmental Assessment of Fusion Power (SEAFP)/Power Plant Conceptual Study (PPCS)

[5] See JET safety analysis. The case assumed ~10% of the tritium in the vacuum vessel was releasable.

> *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.*

SECY-09-0064 discusses this language and the associated legislative history. The staff concluded that fusion energy systems could logically be categorized as a utilization facility provided they are found to be of significance to the common defense and security or could affect the health and safety of the public. In brief, AEA Section 11c. defines "atomic energy" as "all forms of energy released in the course of nuclear fission or nuclear transformation." In its ordinary meaning, "nuclear transformation" includes nuclear fusion, and the AEA's legislative history supports the conclusion that fusion is included within the definition of "atomic energy." Thus, a fusion device can qualify as a "device … peculiarly adapted for making use of atomic energy" under the AEA definition of "utilization facility."

While the provisions in the AEA could support the consideration of fusion energy systems as a utilization facility, NRC regulations defining "utilization facility" in 10 CFR 50.2 do not include fusion devices:

> Utilization facility means:
> (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.
>
> Nuclear reactor means an apparatus, other than an atomic weapon, designed or used to sustain nuclear fission in a self-supporting chain reaction.

Classification of Fusion Energy Devices as Particle Accelerators

Section 11e(3)(B) of the Atomic Energy Act (AEA) defines byproduct material as follows:

> *e. The term "byproduct material" means–*
> *****
> *(B) 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;*
> *****

Building upon the definition in Section 11 of the AEA, the staff first considered if fusion energy systems can be considered particle accelerators, and then considered if there is any radioactive material produced, extracted, or converted after extraction for use for a commercial, medical, or research activity. Particle accelerators are defined in 10 CFR 30.4, and in 72 FR 55868 as a result of Section 651(e) (119 STAT. 806) of EPAct.

10 CFR 30.4 states that:

> *Particle accelerator means 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.*

72 FR 55868 states that:

> *A particle accelerator is a device that imparts kinetic energy to subatomic particles by increasing their speed through electromagnetic interactions. Particle accelerators are used to produce radioactive material by directing a beam of high-speed particles at a target composed of a specifically selected element, which is usually not radioactive.*

A fusion device operates in a similar manner to a particle accelerator since it creates conditions conducive to fusion reactions by accelerating charged particles through electromagnetic interactions in a vacuum and discharging the resultant particulate or other radiation into a medium. Although the energy of the bulk of plasma particles in a fusion device are typically below 1 MeV, the reaction products exceed the 1 MeV threshold. Fusion energy systems will generally:

- Work with charged particles (i.e., ions/plasma),
- Work in a vacuum,
- Discharge the resultant particulate into a medium (e.g., into the plasma, into walls),
- Impart kinetic energy (i.e., raise temperature)
- Use subatomic particles (i.e., plasma components), and
- Accelerate particles (i.e., raise temperature).

The definition of byproduct material in 11e.(3) of the AEA includes any radioactive material that is produced, extracted, or converted after extraction for use for a commercial, medical, or research activity. Most commercial fusion energy systems and technologies under development are meant to produce electricity. Some may be used to produce process heat or a combination of electricity and process heat. Many of the planned fusion devices will produce radioactive material (e.g., tritium) that will be used to sustain the fusion reaction that is necessary for operation and therefore will also meet this requirement. Staff has noted that some fusion devices currently under development will generate radioactive material that is incidental to the production of electricity and will be collected separately. If this radioactive material is then sold and transferred to another licensee, the radioactive material is being used for commercial purposes and would meet the requirements of the byproduct material definition.

The Energy Policy Act of 2005 (EPAct) added radioactive material produced by a particle accelerator to the definition of byproduct material under the AEA. On October 1, 2007, the NRC adopted final regulations “Requirements for Expanded Definition of Byproduct Material” (72 FR 55868) that amended Part 30 to include definitions that expanded the scope of byproduct material and added particle accelerator. The legal definition of byproduct materials supports the treatment of fusion energy systems as particle accelerators.

As reflected in the statements of consideration, the Commission did not explicitly consider fusion energy systems when expanding the definition of byproduct material in the promulgation of the 2007 rule. However, the staff proposes that the similar operating features of fusion energy systems to those included in the Part 30 definition of particle accelerator provides a basis for a risk informed approach to fusion energy system regulation based on the radioactive material types and inventories and radiation produced. Some proposed fusion energy systems will operate with radioactive material or produce radiation during operations that are distributed across multiple components of a site designed to include the overall operating system. Panoramic irradiators regulated under Part 36 use a facility approach to license the activities to ensure that the public and workers are adequately protected from the radioactive material and radiation present. Fusion energy systems could be regulated in a similar manner.

Current Regulatory Treatment of Fusion Technologies

In the United States, research and development activities related to advancing the science of fusion technologies and plasma physics have been largely performed under the regulatory regime of the Department of Energy in facilities such as the DIII-D National Fusion Facility in San Diego, California, and the National Spherical Torus Experiment in Princeton, New Jersey. To a smaller scale, additional research, development, and commercial activities have been performed under the jurisdiction of Agreement States that maintain compatible regulatory programs with NRC's materials program. California, New York, Washington, and Wisconsin have licensed fusion research and development and technology facilities. Additionally, discussions for the licensing of new fusion research and development facilities between Agreement States and fusion technology companies are currently underway in Massachusetts.

Agreement State and Public Engagement to Inform Options

Following Commission direction in SRM-SECY-20-0032 to develop options for licensing and regulating fusion energy system, the staff began extensive stakeholder engagement[6] to obtain input on the potential hazards posed by fusion energy systems and to receive feedback on options for regulating fusion energy systems. This included: six NRC public meetings held from January 2021 through June 2022; a joint public workshop sponsored by the NRC, U.S. Department of Energy (DOE), and the Fusion Industry Association; NRC staff participation in the White House summit, "Developing a Bold Decadal Vision for Commercial Fusion Energy," and the follow-on DOE workshop; international engagement through bilateral government-to-government interactions and International Atomic Energy Agency activities; coordination with the Organization of Agreement States and inclusion of Agreement State representatives on the NRC's fusion working group, and pre-application technology introduction meetings with many private fusion energy companies seeking to commercialize their designs.

The Agreement State representatives actively participated on the fusion energy systems working group that developed the options for this paper and offered presentations at some of the public engagements. Through the involvement of the Agreement State representatives, the working group obtained valuable insight on the Agreement States' experience in licensing fusion research and development activities. The working group and the Agreement States also held four government to government meetings in 2021 and 2022 to provide a status of working group activities and obtain feedback. At the last government to government meeting, the working group discussed the options to regulate fusion energy systems.

[6] See NRC's public webpage on fusion activities for more information on these interactions. https://www.nrc.gov/reactors/new-reactors/advanced/policy-development/fusion-energy.html

Regulatory Framework Options for Fusion Energy Systems

Based on the staff's understanding of the fusion energy systems being considered for future commercial deployment in the U.S. and their associated risks and hazards, the staff has developed three regulatory approach options for Commission consideration:

Option 1 – Regulate fusion energy systems under the utilization facility framework

Option 2 – Regulate fusion energy systems under the byproduct materials framework

Option 3 – Regulate fusion energy systems under a hybrid approach

Option 1 – Regulate fusion energy systems under the utilization facility framework

The NRC staff has determined that fusion energy systems could be classified as utilization facilities under the provisions of Section 11cc. of the AEA if the NRC determines by rule that fusion energy systems make 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." Fusion energy systems have the potential to expose members of the general public and workers to various types of radiation and thereby affect the public health and safety. As a result of the specific hazards posed by fusion energy systems, the NRC would consider ways to risk-inform several requirements associated with the utilization facility regulatory framework developed for large light-water reactors and ensure that the framework is commensurate with the risks and hazards of fusion facilities.

Pros

- 10 CFR Part 53 is being developed in a technology-inclusive, risk-informed, and performance-based manner that once adapted for fusion energy systems could provide an appropriate regulatory framework

Cons

- Potential hazards of current fusion energy systems appear lower than typical utilization facilities and more similar to byproduct material facilities.
- Consideration for how AEA requirements and restrictions for utilization facilities, including those related to financial protection (Price-Anderson); foreign ownership control, or domination; mandatory hearings, etc., will need to be assessed for appropriate application to fusion technologies
- Potential for longer-term rulemaking to tailor the regulatory framework appropriately based on licensing and operating experience.
- Inconsistent with majority of stakeholder feedback received.[7]

If the Commission decides that fusion energy systems should be regulated under a utilization facility framework, the staff would take a three-step approach for ensuring that 10 CFR Part 53 could accommodate fusion energy systems. The three steps are:

1) The staff would perform an assessment of the proposed 10 CFR Part 53 rule and identify in a paper the areas that would need to be revised, modified, clarified, or

[7] For example, see National Academies of Sciences, Engineering, and Medicine. 2021. *Bringing Fusion to the U.S. Grid*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25991.

expanded to provide an efficient, clear, and reliable regulatory framework for fusion energy systems. While the current development of 10 CFR Part 53 is addressing the NEIMA requirement to be technology inclusive, it is focused on the deployment of new fission-based reactors.

2) The staff would engage stakeholders and initiate rulemaking to revise 10 CFR Part 53 or assess if alternative regulations should be developed in a timeframe that would extend beyond the current Part 53 schedule but be completed before the end of 2027. This would comply with the requirements of the NEIMA to provide a regulatory framework for fusion by December 2027.

3) The staff would evaluate, in parallel, the need for new, revised, or additional guidance in support of fusion energy systems being licensed under 10 CFR Part 53 or alternative regulations. This would provide regulatory clarity and predictability to applicants of a fusion energy system.

Option 2 – Regulate fusion energy systems under the byproduct materials framework

Part 30 provides a framework for licensing a wide range of uses for byproduct material. Part 30 also includes specific requirements applicable for licensing larger quantities of byproduct materials including financial assurance and emergency planning. The regulations in Part 30, along with the NUREG-1556 series of licensing guides, are scalable, provide a comprehensive list of technical and regulatory areas required for licensing, and have been used to regulate the potential hazards and risks from a wide range of uses of byproduct material from low risk (e.g., portable gauge) to higher risk (e.g., panoramic irradiators). The Part 30 approach provides a scalable and technology neutral basis for the licensing and oversight of the wide range of fusion energy systems currently under development.

Fusion energy systems could be regulated with a byproduct material framework in one of two approaches to comply with the requirements of NEIMA. The first approach would be using the existing Part 30 regulations supplemented by guidance. The second approach would be development of a limited rulemaking to add fusion energy systems to the scope of Part 30 and develop accompanying guidance. The no-rulemaking and limited rulemaking options are discussed in greater detail below.

The NRC has previously used the Part 30 approach to license facilities designed to utilize large quantities of radioactive materials for commercial use. Panoramic irradiators, which typically contain 1 to 5 million curies of Co-60, have been licensed since the 1960s. Before the adoption of Part 36 in 1993, panoramic irradiators were licensed on a case-by-case basis. This was done under: (1) the general provisions of 10 CFR 30.33, which requires that "equipment and facilities are adequate" and that the "applicant is qualified by training and experience"; (2) the general requirements of Part 20; for example, dose limits and the need for "adequate" surveys; and (3) and limited rulemaking to amend 10 CFR 20.1603 that clarified access control requirements specifically for panoramic irradiators. In addition to the regulations, regulatory guidance was developed and used. Due to the evolution and standardization of irradiator technology and need to update guidance, the agency made the decision to issue a new 10 CFR Part 36 of the regulations that consolidated and standardized the requirements for the licensing and operation of current and future irradiators. Some stakeholders have stated that a similar evolution could occur for fusion technologies with a larger scale rulemaking being pursued in the future (e.g., Part 38).

Option 2a – No Rulemaking Approach to Byproduct Material Framework

Under this option, the existing Part 30 licensing framework would be used to license fusion technologies without changes. Licensing guidance would comprehensively reference the existing regulatory requirements that an applicant for a fusion energy system would need to meet.

Pros

- Part 30 provides an existing framework that is scalable to regulate a wide range of potential hazards and risks.
- Existing fusion devices in Agreement States have been successfully licensed with no additional regulations.
- Anticipated near-term devices could be licensed under the existing definition of a “particle accelerator.”
- Rulemaking may be initiated in the future after gaining insights from licensing and operational experience.
- Guidance development can be completed consistent with existing regulations and with industry progress.
- Guidance would bolster compatibility across NRC and the Agreement States and provide some regulatory predictability for industry and clarity for public stakeholders.

Cons

- This approach is not technology-inclusive of some future fusion designs that do not meet the current definition of particle accelerator. A future rulemaking may be necessary to address regulation of fusion devices that do not meet this definition.
- Staff may identify that rulemaking is necessary to provide regulatory clarity and reliability during the development of guidance which would delay framework implementation.
- For fusion designs that may fall outside of the existing Part 30 framework, lack of a consistent approach among the Agreement States and NRC would not provide regulatory predictability for industry and the public.
- Larger, higher hazard commercial fusion facilities may need license conditions to implement scaling considerations related to emergency planning, physical security, tritium loss, and waste management

Option 2b – Limited Rulemaking Approach to Byproduct Material Framework

Under this option, staff anticipates that limited rulemaking to include definitions for fusion devices would address near-term needs for research and development activities, longer-term needs for commercial activities, and basic requirements for licensing submittals. Content of application requirements would allow for appropriate treatment and scaling of existing byproduct material requirements for fusion energy systems including those for emergency planning, physical security, and design requirements. Licensing guidance would clearly reference other regulatory requirements that an applicant would need to meet.

Pros

- A limited scope rulemaking would ensure a technology-inclusive approach that encompasses all currently envisioned fusion energy system designs.
- New Part 30 application content requirements would allow for risk-informed scaling of existing byproduct material requirements including those for emergency planning, physical security, and facility design.

- Regulations and guidance along with their associated compatibility designations would align fusion oversight across NRC and the Agreement States and provide regulatory predictability for industry and clarity for public stakeholders.
- All pros from Option 2a also apply

Cons

- Rulemaking may be more resource-intensive than a guidance only approach.
- A future rulemaking may still be desired to improve efficiency of fusion device licensing, incorporating lessons learned from licensing and operating experience from early commercial facilities.

Agreement State Compatibility

An Agreement State radiation control program is compatible with the NRC's regulatory program when the State program does not create conflicts, duplications, gaps, or other conditions that jeopardize an orderly pattern in the regulation of agreement material (source, byproduct, and small quantities of special nuclear material as identified by Section 274b. of the AEA, as amended) on a nationwide basis. Management Directive 5.9 "Adequacy and Compatibility of Program Elements for Agreement States[8]" establishes the process the NRC follows to determine when certain proposed or final NRC program elements (including regulations and guidance) must be adopted by an Agreement State. Any Part 30 based regulations and guidance will be a matter of compatibility for the Agreement States.

The development of compatible regulations and guidance would provide consistency across the NRC and Agreement States for a byproduct materials framework. The determination of the compatibility designations for byproduct materials regulations would be done during the rulemaking process and published along with the new regulations to solicit comments. Agreement State staff regularly participate on rulemaking and guidance working groups in the materials area. Given the Agreement States' experience in regulating fusion research and development, their input to the development of rules and guidance process would be critical.

Option 3 – Regulate fusion energy systems under a hybrid approach using either byproduct material or utilization facility regulatory framework based on the potential hazards

Option 3 involves the NRC developing a hybrid approach to address the licensing and regulation of fusion energy systems. Such an approach may be able to better address the differences in potential radiological hazards associated with a variety of fusion technologies and designs. The staff presented two possible ways to develop such a hybrid approach during public engagements with stakeholders. The first approach could be developed to distinguish between different fusion energy systems and address some using a utilization facility model (Option 1, described above) and address others using a byproduct material model (Option 2, described above). This approach is shown in Figure 1 and was referred to as a fragmented approach during interactions with stakeholders. The decision criteria could involve parameters such as estimated offsite consequences or contributors such as inventories of key radionuclides (e.g., tritium).

[8] ADAMS Accession No. ML18081A070

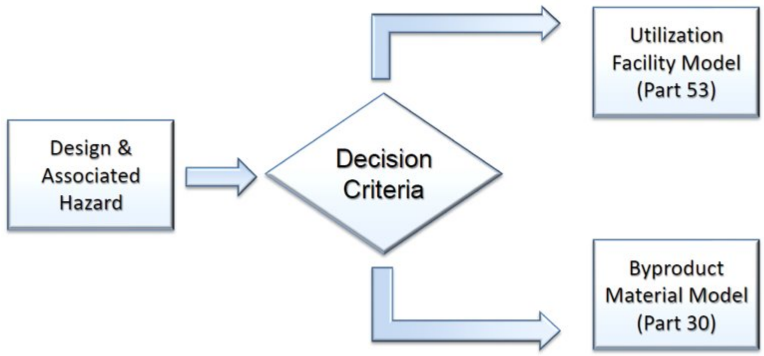

Figure 1: Hybrid Approach within current frameworks (bifurcated)

Another way that a hybrid approach could be developed is a graded approach within a single or consolidated framework that would address any fusion energy system. This approach is shown in Figure 2 and was referred to as the consolidated approach during interactions with stakeholders. As with the previous bifurcated approach, the decision criteria could involve parameters such as estimated offsite consequences or contributors such as inventories of key radionuclides (e.g., tritium) but distinctions between regulatory requirements for different fusion technologies would be located within the same part of NRC regulations (e.g., a new part for fusion energy systems). Examples of graded approaches to addressing potential hazards are provided in some existing NRC regulations and in DOE requirements and guidance.[9]

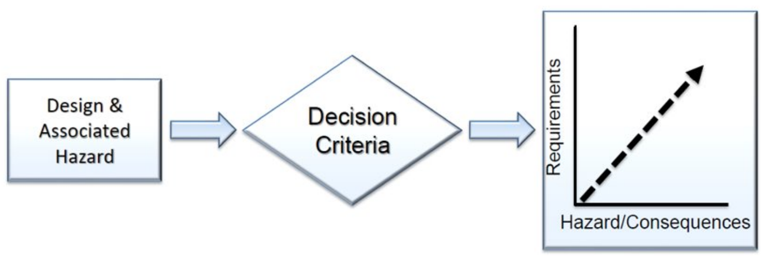

Figure 2: Hybrid Approach within a dedicated fusion framework (consolidated)

After discussions with stakeholders, the consolidated model was recognized to be little different from Option 2 because Part 30 supports such a graded approach and includes the possible longer-term development of a new part (e.g., Part 38). Further discussions of Option 3 will therefore focus on the approach represented in Figure 1.

Pros

- Provides a graded approach that would encompass the full range of potential fusion technologies subjecting facilities with greater hazards to utilization facility requirements. (However, the U.S. fusion industry has indicated that facilities with large tritium

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9 Examples of DOE standards include DOE-STD-1027-2018, "Hazard Categorization of DOE Nuclear Facilities," DOE-STD-3009-2014, "Preparation of Nonreactor Nuclear Facility Documented Safety Analysis," and DOE-STD-1020-2016, "Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities."

inventories or fusion-fission technologies are not currently envisioned to be developed and deployed as commercial facilities.)

Cons

- This option would require a more substantial rulemaking to develop decision criteria and revise regulations associated with both utilization facilities (Part 53) and byproduct materials (Part 30).
- Decision criteria would be difficult to develop given broad array of fusion technologies and related fuels under development and may lead to a complex regulatory system.
- May introduce near-term uncertainty for industry, agreement states, and public stakeholders regarding which framework a particular design will be regulated under.
- Some stakeholders suggested deferring any further evaluations and development of this option until experience gained with early applications and operation of fusion energy systems under Option 2.

If the Commission decides that fusion energy systems should be regulated under a hybrid approach with some treated under a utilization facility framework and others treated under a byproduct material framework, the staff would develop the decision criteria that would be used to categorize them. Factors for the staff to consider would be the potential radiological hazards of the facility and the form of the fusion fuel between one that produces significant neutron activation to those with only minor concerns for neutron activation. The staff could in parallel begin the rulemaking process to add provisions to both Parts 30 and 53 to include fusion energy systems, combining the actions described for Options 1 and 2.