Whitepaper: NRC Looks Ahead to Licensing Fusion Energy

Asking additional questions and thinking differently can lead to a better-formed regulatory strategy long-term

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Abstract

Fusion promises to be a game-changing energy source, able to produce gigawatts of dispatchable clean energy to build energy security and strengthen the fight against climate change. The fusion industry has received more than $4 billion[1] in private investment among more than two dozen companies, technology development is fast accelerating, and the first fusion power plant may well be on the grid by the turn of the decade. The US government has also budgeted $1 billion in public investment for fusion energy advancement via the Biden Administration. To be ready, under the direction of the Nuclear Energy Innovation Modernization Act (NEIMA), the U.S. Nuclear Regulatory Commission (NRC) is evaluating how to craft a technology-neutral, risk-informed, performance-based[2] framework for fusion, with the NRC staff recently issuing an Options Paper[3] with regulatory choices for the Commission to decide on.

There are several different approaches[4] to fusion energy technology. This diverse set of approaches begs questions the Commission will have to answer: *Can these fusion systems be licensed under an existing regulatory framework? Will the NRC need to create a new technology-neutral*

[1] What will it take to build a US fusion industry? (April 4, 2022) Retrieved from: https://medium.com/prime-movers-lab/what-will-it-take-to-build-a-us-fusion-industry-4e4d980a4d91

[2] N. P. Kadambi, Guidance for performance-based regulation, NUREG/BR-0303 (2002)

[3] See Adams Accession Number: ML22273A163

[4] Fusion Breakeven is a Scientific Breakthrough (December 13, 2022) Retrieved from: https://thebreakthrough.org/issues/energy/fusion-breakeven-is-a-science-breakthrough

framework? The NRC staff set out three options for the regulation of fusion, that generally build off the two overarching statutory frameworks available today for regulating radiological activities—(i) the "byproduct materials" framework, or (ii) the "utilization facility" framework. Table 1 provides a summary of our analysis of the proposed Options for fusion regulation. Options 1-3 were proposed by the NRC as potential pathways to licensing fusion energy; however, based on the Breakthrough Institute's assessment, none of them are in full compliance with NEIMA, particularly in the long-term.

To be technology-neutral, the NRC needs a framework that provides a pathway for ALL fusion technologies. The present whitepaper investigates the feasibility of the proposed regulatory approaches from both a practical and legal standpoint. This paper also considers the potential for an Option 2+ capable of satisfying NEIMA, both in spirit and requirements while demonstrating regulatory clarity, practicality, and efficiency. This new Option 2+ would represent the ideal solution for Congress and the NRC to work together to build a cutting-edge, performance-based framework for fusion. With existing NRC resource constraints due to the Part 53 rulemaking, and the uncertainties surrounding fusion technology, creating such a framework is impractical by 2027. Option 2+ more specifically would (1) allow licensing near-term[5] fusion energy under the 10 CFR Part 30 framework to acquire operating experience, (2) extend the NEIMA deadline for long-term fusion and (3) develop a risk-informed, performance-based, and technology-inclusive framework that will allow for rapid innovation and commercialization of long-term fusion technologies under a new 10 CFR Part 38 framework.

[5] The NRC defines "near-term" systems as those fusion energy systems currently contemplated for deployment potentially through the 2030s. See ADAMS Accession Number: ML22273A163 Page 1, 5-7.

Table 1. Assessment of the proposed fusion regulation options compliance with the spirit and requirements of NEIMA: *the presented classifications for fusion regulation were determined based on the applicability of existing utilization facilities (10 CFR 50/52) and byproduct (10 CFR 30) frameworks.*

		Spirit of NEIMA	**NEIMA Requirements**			
	Fusion Regulation Approach	**Enable innovation & commercialization**	**Technology-inclusive**	**Risk-informed**	**Performance-based**	**Can be accomplished by 2027**
NRC-proposed	**Option 1**	No	No	No	No	Yes
	Option 2	In part*	In part*	In part*	In part╬	Yes
	Option 3	No	No	No	No	Uncertain↟
BTI-proposed◈	**Option 2+**	Yes	Yes	Yes	Yes	Not applicable▲

Legend:

◈*Breakthrough Institute's proposal*

* *true for near-term systems, but not for long-term systems*

↟ *due to the undefined technology threshold*

▲ *would require NEIMA timeline extension*

╬*dependent on the approach used in the necessary limited-scope rulemaking*

1. Does the NRC already regulate fusion systems?

Fusion technologies are currently regulated under a byproduct material framework in the Atomic Energy Act (AEA) because they either consume or generate Tritium, an isotope of hydrogen. The AEA defines byproduct material to include:

> *...(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…* [See NRC paper[6]]

Because many future fusion energy systems, including those that use Deuterium-Tritium (D-T) and Deuterium-Helium-3 fuel, will produce Tritium as a part of normal operation, the NRC could regulate them under the byproduct material framework, defined in Title 10 Code of Federal Regulations (10 CFR) Part 30. On the other hand, current nuclear power plants that use fission technology are regulated as "utilization facilities," which include:

> *(1) any equipment or device, except an atomic weapon, determined by rule of the Commission to be capable of making use of special nuclear material in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public, or peculiarly adapted for making use of atomic energy in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public; or (2) any important component part especially designed for such equipment or device as determined by the Commission.* [See NRC paper[7]]

A system may be classified as a utilization facility if the amount of nuclear material produced from these systems can impact defense and security, as well as public health and safety. The NRC is in charge of licensing commercial utilization facilities, including all of the currently operating commercial nuclear energy plants, under regulations 10 CFR Parts 50/52. It is possible that some future fusion energy systems could also fit the definition of utilization facilities under 10 CFR Parts 50/52. However, "utilization facility" is not explicitly defined relative to fusion.

2. Fusion's challenges are real but different than fission's challenges

[6] See ADAMS Accession Number: ML22273A163 Page 10
[7] See ADAMS Accession Number: ML22273A163 Page 8

The characteristics and risks of fusion technologies differ from those of fission reactors, which provides an indication that regulating them both under the same set of rules is inappropriate. For instance, the materials challenge associated with fusion energy systems is not trivial. High-energy neutrons produced from fusion can penetrate the reactor chamber wall into a blanket of surrounding material - which creates radioactive isotopes. In fact, some developers are counting on this to produce fuel. Fusion materials in many cases must be able to withstand unprecedented neutron fluxes and immense thermomechanical stresses while extracting heat energy for extended periods of time. In other words, these materials are expected to satisfy their primary function even as they become weaker over time. But this is problematic because the first wall and blanket structural materials, for at least D-T fusion systems, experience neutron doses that could be several times[8] higher than the design lifetime doses for fission reactors. Moreover, due to the higher neutron energy intrinsic to fusion compared to fission, significantly higher levels of hydrogen and helium can greatly accelerate the degradation of structural materials.

Simultaneously, one of the key benefits of fusion is that it does not use fissile material, and with that goes the requirements for criticality control and related accident management that the bulk of the utilization framework is designed to address. Pressurized thermal shock may not be an issue as well, nor will loss of coolant accidents to the same degree. There also may not be a substantial need for sophisticated operator control for a fusion device given that nearly all actions that damage the key components (such as the vacuum vessel or magnets) will stop the fusion reaction. The safety challenges with fusion are fundamentally more about managing the *materials* issue, and less about controlling the *machine*. With these fundamentally different challenges in mind, is it appropriate to apply the same regulatory requirements and considerations for material qualification in fusion and fission energy systems?

Another important distinction between fission and fusion involves the waste products. High-level waste is defined with fission energy systems in mind. While the waste produced by fusion may not fit the definition of high-level waste, there are still hazards that need to be addressed, including potentially long-lived radioactive waste associated with the activation of structural

[8] Steven Zinkle, Jeremy Busby, Structural materials for fission and fusion energy, MaterialsToday, Volume 12, Issue 11 (2009), 12-19.

materials subjected to high-energy neutron fluxes throughout the material's time in the reactor, or larger quantities of low-level waste.

These challenges create a number of significant questions for regulating fusion under a fission-based utilization facility framework. For example, do existing regulations consider and/or address the potential implications of waste produced from the activation of structural materials in fusion energy systems? It is worth noting that many of the questions regarding fusion waste apply equally to both using 10 CFR Parts 50/52 and 10 CFR Part 30, and speak more to building customized rules for fusion as opposed to choosing between rules.

It is important to address these questions to better position the United States as a leader in fusion energy advancement. But as is, there is a reasonable fear that excessive regulatory requirements will delay domestic deployment of fusion, which would make way for other countries to take the lead on fusion advancement. Lastly, the fusion industry understandably would like to avoid association with fission as much as possible, both in terms of regulations - as the current fission frameworks are burdensome and unwieldy - and in terms of public perception.

3. How is the NRC approaching licensing fusion systems?

To prepare for the next generation of nuclear power, the NRC was mandated by the Nuclear Energy Innovation and Modernization Act (NEIMA) to develop a technology-inclusive regulatory framework for "advanced reactors" by 2027. Per NEIMA, the term "advanced reactors" includes BOTH fission and fusion systems. The NRC intends to meet the mandate of NEIMA for fission energy systems through its proposed 10 CFR Part 53 rule. The draft 10 CFR Part 53 is intended to be risk-informed, performance-based, and technology-inclusive. However, fusion energy systems are not explicitly captured in the proposed 10 CFR Part 53 draft rule, and the NRC staff have stated

that Part 53 isn't designed for fusion.[9] Moreover, many observers, including researchers at the Breakthrough Institute, find that the draft 10 CFR Part 53 for licensing advanced fission energy systems released in September 2022 does not meet those criteria.[10]

To meet NEIMA, the NRC is legally required to establish a technology-inclusive framework for fusion. To that end, the NRC staff has developed three options for the NRC Commissioners to consider[11]: (1) a utilization facility approach under 10 CFR Parts 50/52, (2) a byproduct material approach under the existing 10 CFR Part 30, and (3) a hybrid approach that would allow fusion technologies to be regulated through either framework based on the characteristics of the technology. The NRC staff recommends Option 3. In other words, the NRC or the Agreement states would review each fusion application on a case-by-case basis to determine whether licensing under a byproduct approach or a utilization facility approach may be appropriate.

It is safe to say that many stakeholders disagree with the NRC staff's recommendation. During public meetings with the NRC in March[12] and June[13] of 2022, the Fusion Industry Association (FIA), for example, noted[14] that it would prefer to see fusion energy regulated under Option 2. But before endorsing any of the recommendations, it is crucial to assess their feasibility and maturity from both a practical and legal standpoint.

3.1. Option 1 is unduly burdensome

In general, very few are in favor of Option 1. Stakeholders believe that licensing fusion energy systems as utilization facilities under Option 1 is problematic due to the absence of special nuclear materials in fusion systems under development. Special Nuclear Materials (SNM), are

[9] See Adams Accession Number: ML22273A163 , at 3 (also stated informally multiple times)
[10] NRC Staff Whiffs on Nuclear Licensing Modernization (Dec 12, 2022) Retrieved from: https://thebreakthrough.org/blog/nrc-staff-whiffs-on-nuclear-licensing-modernization
[11] See Adams Accession Number: ML22273A163
[12] See Adams Accession Number: ML22081A057
[13] See Adams Accession Number: ML22158A088
[14] NRC Considers Regulator Approaches for Fusion Energy (November 22, 2022) Retrieved from https://www.fusionindustryassociation.org/post/nrc-considers-regulatory-approaches-for-fusion-energy

fissile materials that could be used in weapons. Without SNM, stakeholders argue that common defense and security is not a concern for fusion energy systems. It is the Breakthrough Institute's view that Option 1 would result in excessive regulation for the safety profile of most fusion designs, considering 10 CFR Parts 50/52 were drafted with only large light water fission reactors (LWRs) in mind. The limited technological scope for licensing fission energy systems under 10 CFR Parts 50/52 led the NRC staff to develop a technology-inclusive 10 CFR Part 53 draft rule for new and advanced fission energy systems. Further, Option 1 does not address NEIMA because 10 CFR Parts 50/52 are not risk-informed or performance-based as is required by that law. Subjecting ALL fusion energy systems to regulation under Option 1 would be impractical because it enforces unnecessary burdensome requirements, requiring extensive requests for exemptions to non-applicable regulations. Moreover, many proposed fusion devices do not seem to meet the legal AEA definition of a utilization facility, which would make regulating them under 10 CFR Parts 50/52 inappropriate. In plain words, regulating fusion under Option 1 is largely like trying to fit a square peg in a round hole. It just doesn't fit. The NRC staff shares that viewpoint and argues:

> *Given these operating characteristics, potential offsite consequences, and the limited contribution of the device to the radiological consequences of potential releases, the NRC staff concludes that near-term fusion devices are unlikely to meet the public health and safety criterion in the AEA definition of utilization facility and therefore recommends that the Commission not determine that fusion devices be broadly classified as utilization facilities from a public health and safety perspective at this time.* [See NRC paper[15], emphasis added].

The possibility of regulating fusion under Option 1 depends on whether the definition of utilization facilities is revised to clarify its applicability to fusion energy. Option 1 could, in theory, be accomplished by 2027 if the Commission decides to regulate fusion under a utilization facility framework, but NEIMA's other requirements would not be met. The decision to revise the definition of utilization facility could be done by Congress amending the AEA. Otherwise, it is up to the Commission to issue its interpretation of the

[15] See Adams Accession Number: ML22273A163 Page 14

applicability of the definition of utilization facility, as it currently reads. The NRC staff stated that near-term fusion devices are unlikely to meet the definition of utilization facilities, hinting that long-term fusion devices may require additional regulation, on a case-by-case basis.

3.2. Option 2 is viable for near-term fusion

Option 2 presents a familiar approach to licensing fusion devices under 10 CFR Part 30. At first glance, Option 2 appears to be the most practical approach for regulating near-term fusion energy systems. Some stakeholders, including the FIA, strongly support[16] licensing under Option 2 in part because fusion devices have already been licensed this way for decades, and, FIA argues, those regulations have provided adequate protection of public health and safety. There are also obvious benefits to starting with a regulatory system that is already in place and ready to go. Because it is a somewhat flexible regime, it could *arguably* be risk-informed and performance-based for the first generation of fusion power plants (or beyond if they stay relatively the same thereafter).

But on second glance, Option 2 lacks holistic compliance with NEIMA, only satisfying the risk-informed, performance-based, and technology-inclusive requirements for near-term fusion technologies. For example, the NRC paper does not indicate an intention to ensure Option 2 is performance-based. The approach taken to perform a limited rulemaking or subsequent approaches defined in guidance could transform Option 2 to be wildly prescriptive or truly performance-based.

The FIA argues (and the NRC staff seem to similarly posit) that Option 2 is in alignment with NEIMA to achieve the goal of timely deployment by 2027. While true, Option 2 could impose restrictions that create regulatory uncertainty for licensing long-term fusion technologies. The

[16] NRC Considers Regulator Approaches for Fusion Energy (November 22, 2022) Retrieved from https://www.fusionindustryassociation.org/post/nrc-considers-regulatory-approaches-for-fusion-energy

NRC staff likewise recognizes that Option 2 could present regulatory uncertainty long-term for fusion devices:

> *Some devices using aneutronic technologies may fall outside of the AEA byproduct material provisions.* [See NRC paper[17]].

The crux of the issue is that under Option 2, the NRC staff would not substantially modify the Part 30 rule to be technology-inclusive and just perform a "limited-scope" rulemaking, especially because of the short timeline remaining under NEIMA.[18] Option 2 thus does not prepare for long-term future devices that may differ in characteristics from near-term technologies. These characteristics could make them more complex (e.g., if they become very large facilities), or even simpler and safer (e.g., they continuously improve and streamline design and safety). Take 10 CFR Parts 50/52, for example, these frameworks were drafted based on the characteristics of large LWR designs and not the newer advanced fission reactor designs. It is not unreasonable to predict that fusion technology will undergo similar evolution, requiring flexibility to adapt to the technology.

As the NRC staff argue, especially as fusion scales, relying on a Part 30 framework essentially as-is "could reduce clarity and reliability for fusion energy system applicants. This could result in licensing inefficiencies, including increased use of applicant and staff resources on pre-application engagement and development of application-specific exemptions, license conditions, hearing orders, or separate rulemaking." [See NRC paper[19]]. To provide flexibility and maintain clarity for a larger range of applicants, it is crucial to ensure that the limited scope rulemaking and regulatory guidance developed at a later stage is performance-based. NEIMA mandates a performance-based approach for this reason.

Commissioner Caputo, who recently voted[20] on the matter, believes that Option 2 provides regulatory efficiency, consistency, safety, and certainty for near-term fusion technologies;

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[17] See Adams Accession Number: ML22273A163 Page 18
[18] See Adams Accession Number: ML22273A163 Page 17-18
[19] See Adams Accession Number: ML22273A163 Page 18
[20] See NRC Accession Number: ML23039A061

however, the Commissioner also recognizes that "as fusion energy technology advances, designs may arise for which regulation under Part 30 isn't appropriate." The Advisory Committee on Reactor Safeguards (ACRS) - also has concerns about Option 2, stating that scaling up 10 CFR Part 30 as fusion develops "could result in a patchwork of regulations". [See ACRS letter[21]]. However, it is noteworthy that Option 2 provides an established path to gather operating experience on the near-term fusion energy systems. The Breakthrough Institute and other stakeholders agree with the NRC Staff's reasoning behind Option 2:

> *This would address near-term needs for continued developer research and development activities, enable regulatory clarity and reliability for early commercial deployment, and lay the foundation for addressing the longer term needs of a commercial fusion energy industry.* [See NRC paper[22]].

Stakeholders like the FIA have argued for using Option 2 as it allows developers and regulators to stay focused on the devices under development today, not hypotheticals. The first fusion energy systems could be licensed under 10 CFR 30 to collect operating experience, until additional action (perhaps in the form of a new 10 CFR Part 38 as discussed later, amending existing 10 CFR 30 language, or issuing additional guidance for 10 CFR 30) is needed. However, the NRC staff has drafted this paper[23] to comply with NEIMA, which requires technology-inclusive frameworks - this means technologies in the near- and long-term.

3.3. Option 3 conceptually meets NEIMA but creates notable uncertainty for fusion technology categorization

As individual approaches, the first two options present challenges. There is, however, conceptual potential in Option 3, which combines them. Such a system would allow for near-term

[21] See NRC Accession Number: ML22290A177 Page 2
[22] See Adams Accession Number: ML22273A163 Page 17
[23] See Adams Accession Number: ML22273A163

deployment of fusion energy systems under Option 2, but the flexibility to potentially license long-term fusion energy systems under Option 1.

Still, while this strategy appears to meet the requirements of NEIMA, the challenge remains that it sticks within given frameworks and does not truly tailor for fusion. The problems with Option 1 remain, only now limited to a set of companies falling on the other side of a potentially arbitrary (and very hard to create) threshold. Moreover, it is not clear what the NRC would license under Option 1 and what it would license under Option 2, creating substantial regulatory uncertainty. One of the main points of confusion is the legal definition of "utilization facility" and its ambiguous applicability to fusion systems. That leaves the threshold between using 10 CFR Part 30 and Parts 50/52 up in the air, which has significant challenges for licensees.

Option 3 also carries a heavy burden in that it would require substantial guidance and rulemaking to retrofit fusion to fission-based Parts 50/52 rules (see Section 3.1 for limitations of Parts 50/52). Despite this uncertainty, NRC staff believes Option 3 satisfies NEIMA by presenting the potential for a technology-neutral approach:

> *Under this option, to create an approach that would be technology inclusive of all potential fusion energy systems, the NRC staff would develop a hybrid framework… This hybrid framework would use decision criteria to determine whether a fusion energy system should be licensed and regulated using a byproduct material approach as described in Option 2 or a utilization facility approach as described in Option 1.* [See NRC paper[24]].

The ACRS agrees with NRC staff that Option 3 should be pursued, stating that the hybrid approach provides needed regulatory flexibility given the diverse fusion design options [See letter[25]]. But Commissioner Caputo has disagreed[26], stating that "there are significant disadvantages to the staff's recommended hybrid approach, namely that the hybrid approach creates regulatory

[24] See Adams Accession Number: ML22273A163 Page 19
[25] See NRC Accession Number: ML22290A177 Page 1
[26] See NRC Accession Number: ML23039A061

uncertainty for developers and that it is premature to pursue the kind of fusion rulemaking the hybrid option would require given that so much about commercial fusion technology is still unknown.

In summary, even though this option was suggested to attempt to meet NEIMA's requirements, it does not meet its spirit because it attempts to fit fusion under an approach intended for a different technology, under potentially arbitrary decision criteria, which could likely hinder innovation and rapid commercialization. NEIMA was, moreover, introduced to streamline the reactor licensing process by mandating technology inclusivity, which is not explicitly satisfied under Option 3 because fusion applicants would require many exemptions to obtain a license under 10 CFR Parts 50/52.

Other stakeholders also recognize that Option 3 is accompanied by regulatory uncertainty for developers because it is unclear what a hybrid approach could look like. And, while different fusion technology approaches will certainly carry different risk profiles, differential application of regulatory pathways could subject specific fusion technologies to undue regulatory burden on a somewhat arbitrary basis, which is not risk-informed, or technology-inclusive. The FIA is concerned that Option 3 would require extensive and needless rulemaking, further echoing concerns about where exactly the line will be drawn between technologies that can use 10 CFR Part 30 and those that will have to be licensed as utilization facilities.

4. Key questions and potential future issues for fusion

Although the three options presented by NRC staff each have some merit, all are flawed from a legal and/or practical viewpoint. For that reason, the NRC needs to develop another option. More specifically, building a comprehensive fusion framework that demonstrates regulatory clarity, practicality, and efficiency. As the NRC moves forward toward meeting the spirit of NEIMA, it will have to address several key questions and issues.

Two Overarching Questions: Legally, NEIMA requires the NRC to develop a regulatory framework that is risk-informed, performance-based, and technology-inclusive for licensing advanced reactors. In other words, the new framework for advanced reactors should be comprehensive enough to accommodate iterative and long-term technological innovation. The two key questions that should be asked off the bat are:

- **First:** Should the framework include both fission and fusion - even though they operate based on fundamentally opposing processes?

- **Second:** Should the framework be established by 2027? NEIMA says it should, but it was thinking about fission reactors. How realistic or necessary is that requirement when it comes to fusion, which is many more years away?

With these overarching questions in mind, it should be noted that NRC jurisdiction is limited by the existing legal landscape. More plainly, any and all proposals by the NRC must abide by existing laws or Commission decisions. The NRC staff cannot propose options that depend on decisions that can only be made by Congress.

Practically, fission and fusion produce energy in innately different ways. It follows that the associated risks and hazards, including waste, are not directly translatable from one to the other. For example, the definition of high-level waste specific to fission systems is not applicable to fusion systems, but that does not necessarily mean that fusion systems will not produce unique waste that is specific to fusion (or have very different quantities of waste). Of course, crafting regulations around these facts would require defining a category of waste specific to fusion energy systems, recognizing that currently licensed fusion devices are not energy systems.

Building off of the two overarching questions above, there are other questions to consider when assessing how fusion systems should be regulated, some of which fall under the purview of the Commission, while others are the province of Congress.

Some NRC-related questions include:

1. While both fission and fusion are intended to create electricity (whereas other devices regulated under Part 30 do not e.g., particle accelerators), does that justify regulating them under the same framework even though the risks and hazards associated with each are significantly different?
2. Will the Commission take a stance on whether/how fusion devices fall under the definition of utilization facility? Is asking Congress for statutory clarification beneficial to align definitions with the technical case?

Some Congress-related questions are:

5. Since existing regulations of utilization facilities were created based on the definitions and processes related to fission technology, how can fusion be suitably regulated under fission regulations?
6. Would Congress amend the definition of a utilization facility under the AEA to explicitly include/exclude/partially include fusion?
7. Would Congress amend NEIMA to separate the requirements for fusion from fission, such that fusion is not subjected to the 2027 deadline?

The answers to these questions are largely up to Congress and/or the Commission. The following section describes actions that could be taken to minimize regulatory uncertainty for licensing fusion energy.

5. What could the future look like?

There is no simple answer to the key questions posed. Answering any of them requires an assessment of the possible outcomes of a series of related choices. We might think of the task ahead as a decision tree, where the main choices can be binned into two pathways:

1. **Make no changes to the underlying law/policy.** Option 2 could satisfy NEIMA but just for the short term and may not be technology-neutral long-term. Option 3 has conceptual potential in that it provides multiple avenues for licensing fusion technology based on its specifications. However, Option 3 does not fundamentally satisfy the requirements of the risk-informed, performance-based, technology-inclusive requirements of NEIMA. Conversely, making adjustments to existing law would change the status quo. Changing the status quo is an uphill battle, though certainly not out of the realm of possibility. These changes would require intervention from Congress and/or the Commission.

2. **Make some changes to the underlying law/policy.** If one of the following actions are taken, then there is an opportunity to address critical flaws in the options presented by the NRC staff:

    - *Congress dependent (A).* If Congress amends AEA to redefine "utilization facility" to explicitly exclude fusion, the only viable option would be Option 2, as both Options 1 and 3 make use of the utilization facility frameworks. But without any further action, Option 2 would not satisfy the technology-neutral requirement of NEIMA long-term.

    - *Congress dependent (B).* If Congress takes additional action to only amend NEIMA's timeline with respect to fusion technology, then a hybrid approach of Option 2 and a new fusion-specific framework would satisfy the technology-neutral requirement of NEIMA.
        - Without the constraint of the 2027 deadline, there are a number of pathways to start with Option 2 and build from there as the technologies mature. This could include drafting a completely new 10 CFR Part 38[27], which would ideally consist of high-level performance objectives suitable for all fusion technologies with the details of how to achieve said objectives up to the developer, with possibilities in guidance.

[27] At least one technology developer has suggested a 10 CFR Part 38 concept to the Commission. ML22318A265 (page 71); ML22243A083 (page 15).

- Another path could be to initiate a rulemaking on 10 CFR Part 30 to add relevant additional requirements as the need arises.

- *Commission dependent*.
  - If the Commission interprets all fusion facilities as "utilization facilities," then only Option 1 would be viable; however, it would not satisfy NEIMA. Alternatively, if the Commission decides that fusion does not fall under the definition of a utilization facility, then only Option 2 would be viable, but that still would not satisfy the technology-neutral requirement of NEIMA. In the latter instance, a new framework (e.g., 10 CFR 38) would be necessary.

6. Breakthrough Institute's Proposal: Option 2+

Of the three main pathways that require intervention by Congress or the Commission, The Breakthrough Institute believes the Congress-dependent (B) pathway is the only route that would allow appropriate regulation of fusion energy in accordance with the risk-informed, performance-based and technology-inclusive requirements NEIMA. As a result, the Breakthrough Institute proposes Option 2+ that not only has the potential to meet the mandate of NEIMA, but also achieve regulatory clarity, efficiency, and practicality. To summarize, the new Option 2+ would require the following changes:

1. License near-term fusion energy technologies under the byproduct materials Part 30 framework.
2. Extend the NEIMA timeline specifically for fusion energy technology
3. Create a new rulemaking for long-term fusion energy under a new 10 CFR Part 38 framework, timed to track with industry progress.

The first action can be concluded swiftly, via Commission action in response to the Options Paper. The second action will need a small Congressional amendment, but could potentially be incorporated as a technical clarification. The third action would require modest Congressional

support and oversight over time, and can be timed to grow with the industry.

These actions are a necessary fix to the NRC options (and NEIMA) to produce a technology-neutral, risk-informed, and performance-based licensing framework for fusion energy systems, in the long-term. But it is also an opportunity. As fusion deploys, operating experience and insightful approaches to licensing will be obtained to enhance both safety and efficiency. New regulatory concepts may need to be explored—for example, if fusion can be mass-manufactured, a licensing approach that enables design-based licensing, instead of project-based licensing may need to be incorporated. Different licensing practices may need to be established related to tritium management and waste at scale. The public's perception and interactions around fusion may be different and warrant different ways of public engagement as part of licensing. Setting out the above roadmap can not only meet the requirements of NEIMA, but also give Congress and the NRC a long-term vision for the deployment of fusion that builds excitement around what's coming next.

7. Conclusion

The future of fusion technologies is incredibly promising, but to reach its full potential, fusion must be aptly regulated. As with many challenges, there is no easy answer to how exactly to accomplish this. The current options proposed by the NRC staff are all flawed on either legal or practical grounds. This whitepaper provides an assessment of the Options presented by the NRC and proposes solutions to improve the options for regulating fusion energy in the near- and long-term as mandated by the risked-informed, performance-based, technology-inclusive tenants of NEIMA.