Licensing Advanced Nuclear Reactors:
Regulatory Innovations and Future Challenges

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ABSTRACT

Fulfilling the promise of advanced nuclear will, particularly in the U.S., require addressing issues of cost competitiveness. A major part of this challenge is the development of a regulatory framework that allows certainty and clarity for advanced reactor vendors navigating the licensing process. Historically, the NRC has employed a prescriptive approach that has been adapted to the realities of conventional light water technology. Recent legislation and an emerging advanced nuclear industry in the U.S. has prompted the NRC, in close communication with stakeholders, to begin formulating a risk-informed, performance-based, and technology-inclusive framework that should improve the efficiency of regulatory reviews of advanced reactor designs. The ultimate objective of these efforts is facilitating the safe and secure commercialization of advanced nuclear technologies so that they can meaningfully contribute to broader goals (decarbonization, energy reliability, U.S. geopolitical interests) in a timely manner.

SUMMARY

There are about 50 vendors talking about the possible introduction of advanced reactors of various designs. They promise lower cost (both in capital and operational cost), greater safety, technical simplification, possibly higher temperature of operation, greater fuel efficiency, less waste production, and greater nonproliferation protections. Lower cost is the primary factor driving the success of the next generation of reactors in the US.

- One cost challenge is the regulatory cost of reactors, and there is a severe regulatory challenge because they use non Light Water Coolants. The existing regulations are prescriptive and focused on the light water reactors. They have many regulatory requirements that are applicable to LWRs, but not advanced designs.
- Vendors need some confidence that they know what regulatory burdens they will confront; they need this information early enough to tailor their reactor development towards successful licensing and regulation.
- There are great opportunities with the advanced reactors to reduce cost: safety systems can be simpler. Those regulatory requirements may appropriately be relaxed. Furthermore, some designs offer smaller sizes and slower core release which may open the possibility of reducing EPZ requirements, allowing these new reactors to replace coal plants in populated areas. Many of the advanced designs can build in operational security into the design, which may reduce costs of operational security. Containment systems can also allow for passive safety that may reduce costs on meeting safety requirements. SMRs and Microreactors also offer a smaller capital cost, which would open market opportunities towards buyers with smaller overall budgets.

- There are opportunities to create new regulations for the advanced designs that can be technology-neutral. The aim is to have a risk-informed performance-based licensing system. DOE and a number of other organizations have been invested in creating such a process for newer reactor designs. NRC is looking to respond to the demand of advanced reactors by accelerating its licensing program. NRC is looking to complete the regulatory modernization by 2024. In the meantime, NRC is attempting to provide as much assurance as possible in terms of staff level technical reports, topical reports, accommodating white papers, and other ways to provide assurances to vendors.

Nuclear energy is important to the national strategy in meeting national goals in the area of national security. There's growing recognition that nuclear needs to be part of the solution to decreasing carbon emissions, and it goes along with utilities taking up nuclear in their energy mix.

- A decarbonization mindset needs to be brought to the table to discuss climate change efforts, and nuclear is the best solution for baseload clean energy. Decarbonization has to be done in a way that ensures reliability and affordability, and nuclear can play this role.

The nuclear industry is facing new dynamics. Nuclear energy has record level funding for new technologies, and DOE is announcing awards for the ARDP and UAMPS projects.

- There is more federal support for nuclear, and broad-scale nuclear deployment is possible in the long-term. Many of the challenges that new technologies bring to the framework will be balanced by the market opportunities that the new reactors can provide through advanced capabilities and significant cost reduction capabilities. The NRC can license new and advanced reactors today without any changes. The point of the modernization process is to increase efficiency of the licensing process to allow the new designs to achieve market readiness in a more-timely manner.

The Part 53 rulemaking is a once-in-a-lifetime opportunity for nuclear. When you boil down the schedule, you really have a year to get the content of the rulemaking right. Because this is so significant, and it will be the rule that all reactors will follow after 2024, this rulemaking has to be transformational. This is the double challenge: it has to be transformational, but it has to be done in an ambitiously small amount of time.

- Activities like the licensing modernization project were aimed to assist in this rulemaking, so the efforts are not being started from scratch. If the NRC wants to avoid making mistakes, there must be continued and increased openness and engagement as it deals with upcoming issues.
- Stakeholders of all types will have to stay transparent and flexible in dealing with upcoming issues, otherwise deadlines will not be met. Further, the guiding principle that must be used must be a much deeper appreciation of risk. Determining what has to be regulated and what doesn't should be guided by risk.

Performance-based regulation will have to drive everything moving forward. The interaction with stakeholders is going to be essential. This will be a difficult process to gather and deal with these comments. NEI is taking a lead effort in building a group of people to deal with this.

- This effort will take many resources from NRC and the industry side. NEI and NRC have been taking weekly engagements, and the industry has been providing feedback as the NRC proposes ideas. Furthermore, stakeholders are also looking to initiate conversations by proposing ideas to NRC.
- There are special areas where there will be particular challenge, one being fuel. We have a lot of experience with existing 5% enriched Zr-cladded fuel, but as we change the cladding and increase the fuel enrichment, there will be a series of challenges. NRC has a process for evaluating fuels that takes time because they want to test the fuel under accident conditions. This testing is difficult to rush. There is a lot of work on this, and there is significant research on the TRISO fuels. The other more different fuels may provide a larger challenge, and vendors will need early guidance on what is going to be required.
- DOE has a requirement for the ARDP program to be operational within 7 years. These designs are likely to be using fuels that haven't been used in the NRC before, so we will have to find licensing options within the required timeframe. In the past, it has taken 20 years or more to regulate fuel, but this is not going to be acceptable moving forward.

There's been an option that NRC has put on the table: the NRC is willing to license a prototype plant that can be sited somewhere in Idaho to test the subsystems under normal operations. This can be used to validate codes and help in licensing. After this is proven, then the NRC can agree to operate at the different conditions. This should be attractive to vendors, but I haven't yet seen any vendors jumping at this opportunity.

- It should be an option for NRC to license a prototype, but the reason it's not preferred is that the developers can demonstrate reasonable assurance of safety without this, and the addition of additional safety features for the prototype would increase cost.
- Commercial reactors that need to compete in the market would shed some safety features, as overcompensating on safety isn't necessary outside of a prototype plant in the absence of NRC regulations.

A technology-inclusive rule would not exclude the licensing of other technologies such as LWRs. How do you see the Part 53 licensing affecting large reactors and the current fleet?

- The NEI letter about part 53 opened the door. I think everything contemplates that you would not remove Part 50 or 52; you would only add part 53 as an option. Existing plants may alter their licensing but they will likely not come in using the new licensing part. Part 53 can be used to drive risk-based assessments in the NRC licensing process.
- If Part 53 excludes a particular technology such as the LWR, it's difficult to call it technology-inclusive. What the industry is attempting to achieve with Part 53 is not just

technology-inclusiveness, but also addressing the patchwork of regulations that have been added and created over the years. As the pieces are all put together, the goal is to create a more efficient safety paradigm.

QUESTION & ANSWER

Q: *You described a number of opportunities provided by these advanced reactors being considered, including minimal radioactive material release in the case of an accident. On the security side, many of these reactors will use significantly higher enriched fuel than current power reactors, perhaps requiring more stringent physical protection measures. Do you think the regulatory guidance that exists or is being developed is adequate to inform reactor vendors what physical protection measures they may need to take to seal these reactors? Do you have specific recommendations on physical protection regulatory requirements?*

A: This is an area where physical security requirements are not broadly public. The NRC has described that it's undertaking a limited rulemaking in this area, but it won't largely be public. Nobody is talking about the usage of highly enriched fuel. These reactors will take enrichment up to 20%, so they will have higher enriched fuel which will raise safety considerations as well as security related issues. Some of the reactors are going to be deep underground so they will be less vulnerable to certain attacks.

A: In terms of security as a design basis, NRC has a rulemaking ongoing that would recognize security by design. NEI is developing guidance to help that limited scope rulemaking. The fuel, while more highly enriched, is still not high enriched uranium, so it's not anticipated that additional rulemaking will be required.

Q: *Why do you believe that it is an either/or of "fast" or "transformational"? Should we not be asking NRC to be the most transformational as expeditiously as possible?*

A: I agree with the sense that yes, we should be asking NRC to be both transformational and fast. The challenge is not an either/or situation. We believe it can be both. The point is that it's merely an additional challenge. There's a critical path timeline that's the sequencing of activities. Greater than that, there's a level of effort required that's needed to be transformational. While we're ramping up to provide those hours, and it's essential to be able to manage the efforts efficiently as to focus resources appropriately.

A: Of course they should be both. But let's focus on the "fast"; rulemaking is process that NRC and the industry can't always control. You have to be careful that in moving forward, you are creating something that people can recognize as addressing the issues. That's the only thing I can see because as of now, I believe NRC has the ability to address these issues.

Q: *I would be grateful for presenters' thoughts on the following proposition: quantitative evaluation of safety performance needs to be thoroughly validated with actual plant operating experience. A GW-scale molten salt reactor is very far from current operational experience. Regulatory decisions should be based on high-quality experimental data and conservative*

assumptions. A full regulatory regime for an advanced nuclear design will require data from a prototype, and likely from a FOAK.
A: That's why I raised the conversation about a prototype. This may be a vehicle by which you gain the necessary information to provide NRC and vendors comfort to predict the market. This may not be necessary for many designs. We know a lot about TRISO fuel designs. Some of the other advanced fuel designs may need additional data. I agree with the thrust of the comment.
A: It's an important point to consider. The quantitative method does have a process for handling areas of uncertainty. We're encouraging the NRC to not be completely risk-based. Oklo's application was a more deterministic approach. There may be ways to include deterministic approaches in a risk-based process.
A: There may be probabilistic techniques. The way you handle that is by additional margin so you have confidence that you have limits that are highly unlikely to be exceeded. There's a tradeoff that needs to be made. Do you live with uncertainty and add in additional margins, or do you seek real data?

Q: *Who would invest in a prototype? Wouldn't it have to be the government?*
A: It wouldn't have to be the government. If it's a prototype and it's not generating electricity, it's entirely a cost burden. There are some companies looking to fund a demonstration plant that may not receive revenue from entirely private funding such as Oklo.

Q: *Regarding the challenge of approving new fuels by the NRC, do you see an operational Versatile Test Reactor as part of a critical path to licensing of new reactors?*
A: They do have the capacity to test fuel types for various reactors. It will be a SFR based design, but they will have other test loops for different coolants. We have to build that reactor first, then you have to get the test loops operating with the different fuels in it. We're not talking about anything as a near term response for vendors.
A: The VTR is not required to be able to license some of the advanced reactor designs. The timeline for the VTR may not be able to aid in licensing near term commercialized reactors. The VTR will be able to help extend operational phases and increase operation efficiency.
A: Independent of all this, there is much work on accident tolerant fuels anyway.

Q: *With regards to safety features against accidents any thoughts on the role of artificial intelligence (AI) technology and current status of deployment of AI in nuclear based power generation?*
A: The AI question started with microreactors, and they're looking at how to automate operations. This will be a licensing consideration if you're transferring operation of the reactor from humans to equipment.

Q: *Many people are looking at how advanced reactors could complement variable renewables through load following. Automated control by the ISO/RTO operater would provide faster*

response and make this capability more valuable and more competitive with natural gas. Could you comment on the related licensing issues?

A: Much of what developers are looking at for advanced technologies is that the balance of plant systems with renewables will not impact safety. If they don't have impact on safety, they won't need to factor into the licensing.

A: I think it's inevitable that we'll have more and more renewables on the grid. The nuclear part of the grid will have to complement them in many ways. Nuclear makes more money as they run longer. To include renewables, you will want storage. The advanced reactors have the promise of opening up opportunities of load following which current LWRs cannot. Furthermore, these reactors may operate at higher temperatures that open economic opportunities such as process heat for industrial needs.