Options for Implementing the Advanced Nuclear Energy Licensing Cost-Share Grant Program

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I. Introduction

One potential barrier to the licensing of advanced nuclear reactors is the high cost associated with licensing activities. The NRC charges applicants using hourly fees for licensing reviews as part of their mandated cost recovery funding model. The current hourly fee for NRC licensing reviews is $300/hour and license reviews can cost applicants millions of dollars. The Advanced Nuclear Energy Cost-Share Program at the Department of Energy's Office of Nuclear Energy (DOE-NE) enables grants for advanced reactor developers to help pay a portion of their licensing cost, enabling earlier NRC engagement by smaller companies. The program was originally established in the Nuclear Energy Innovation Capabilities Act (42 USC 16280), and now has $5 million appropriated to it through the Appropriations Act of 2023. This program is a valuable near-term step to reduce barriers to advanced reactor licensing, and continued funding will enable the program to effectively support licensing and commercialization activities by advanced nuclear energy developers. Implementing the Advanced Nuclear Energy Cost-Share Grant Program requires DOE-NE to prioritize licensing activities that could be supported by the program and create metrics for evaluating grant proposals and awarding grants.

There are four main factors that should be considered when considering the different licensing activities that could be supported by the Advanced Nuclear Energy Cost-Share Grant Program. They include:

- Type of licensing interaction
- Project maturity
- Applicability of licensing interaction
- Topic of licensing interaction

These factors impact the activities that could be supported by the Advanced Nuclear Energy Cost-Share Grant Program. A summary of the high-priority characteristics for each factor are summarized below and detailed in following sections in this memo. Additionally, examples of projects that would be well suited for the program, with respect to these four factors, can be found in section VI below.

1. *Type of licensing interaction* - Pre-application interactions and supplementary submission reviews (white papers, technical reports, and topical reports) that can reduce barriers to subsequent advanced reactor license application submittals and reviews
2. *Project maturity* - Early-stage projects (pre-conceptual, conceptual, or detailed design projects) could enable the incorporation of licensability and regulatory insights throughout the design process and help resolve long-lead time regulatory issues OR later-stage projects (RTR or FOAK reactor projects) can support applicants and communities (specifically disadvantages communities) at a key stage of deployment and reduce the burden on new applicants

3. *Applicability of licensing interaction* - Preference for more generally applicable licensing interactions that can applied to multiple advanced reactor technologies (generally applicable to all advanced nuclear technologies or applicable to a class of reactor technologies) or provide specific novel insights that could help accelerate licensing of research, test, and demonstration reactors (applicable to a specific design or license application)
4. *Topic of licensing interaction* - Preference for more generally applicable licensing interaction topics that address higher-level interpretations of policy, programmatic, and regulatory questions or generally applicable design and analysis methodological topics. More specific topics that provide help accelerate licensing of research, test, and demonstration reactors are also valuable to support

These considerations can help guide DOE in the prioritization of support of projects by Advanced Nuclear Energy Cost-Share Grant Program.

II. Type of Licensing Interaction

Different types of licensing interactions between applicants and the NRC can first be broadly binned across several categories:

- Pre-application activities
  - Pre-application meetings
  - Review of regulatory engagement plans
- Supplementary submission reviews
  - White papers
  - Technical reports
  - Topical reports
- Application submission reviews
  - Construction permit/operating license (CP/OL)
  - Combined license (COL)
  - Standard design approval/standard design certification (SDA/SDC)
  - Manufacturing license (ML)
  - Early site permit/limited work authorization (ESP/LWA)

These categories help to characterize different licensing activities that could be supported by the Advanced Nuclear Energy Cost-Share Grant Program. It is important to ensure, however, that the activities supported by the program make the most judicious use of the $5 million of available funds. This requires consideration of both the cost and the impact of different licensing activities on the development and deployment of advanced reactors. Table 1 lists the projected costs from different licensing activities.

Table 1. Published NRC Licensing Activity Cost Data

Activity	Average Staff Hours	Average Cost ($300/staff hr)	Additional Average Contractor Costs	Total Average Cost	Source
Commercial DC	179,395	$53,818,500	N/A	$53,818,500	ML23018A174
Commercial COL	89,261	$26,778,300	$5,020,000	$31,798,300	ML23018A174
Commercial ESP	29,104	$8,731,200	$2,760,000	$11,491,200	ML23018A174
Research and Test Reactor OL	22,450	$6,735,000	$70,000	$6,735,000	ML23018A176
Research and Test Reactor CP	15,796	$4,738,800	$70,000	$4,738,800	ML23018A176
Topical Report - High Complexity	3,000	$900,000	$425,000	$900,000	ML23018A176
Topical Report - Medium Complexity	1,350	$405,000	$175,000	$405,000	ML23018A176
Topical Report - Simple	600	$180,000	$105,000	$180,000	ML23018A176

The NRC published data summarized in Table 1 highlights that the total average billed cost for application submission reviews (CP/OL, COL, SDA/SDC, ML, and ESP/LWA) may exceed $5 million dollars and would fully utilize the program funding. As a result, it is unlikely that the program could meaningfully support application submission reviews without a substantial increase in program funding. The Advanced Nuclear Energy Cost-Share Grant Program should therefore focus on supporting pre-application interactions and supplementary submission reviews (white papers, technical reports, and topical reports) that can reduce barriers to subsequent advanced reactor license application submittals and reviews.

III. Project Maturity

The context of the licensing activities is important when creating criteria for the solicitation and evaluation of licensing cost-share grant proposals. The context for an applicant's interactions with the NRC can be generally characterized based on the maturity of the reactor project and status of the licensing activity:

- Project maturity
  - Pre-conceptual or conceptual design project
  - Detailed design project
  - RTR reactor project
  - First-of-a-kind (FOAK) reactor project
  - Nth-of-a-kind (NOAK) reactor project

The most mature projects (NOAK reactor projects) will not likely have significant pre-application interactions or supplementary submissions reviews beyond site-specific regulatory reviews to support approval of standardized license applications. As a result, it is not likely that NOAK

reactor projects would benefit substantially from the level of support available through the Advanced Nuclear Energy Cost-Share Grant Program. Prioritization of regulatory support for projects at other stages of maturity can vary based on overall DOE-NE goals. Support for early stage projects (pre-conceptual, conceptual, or detailed design projects) could enable the incorporation of licensability and regulatory insights throughout the design process and help resolve long-lead time regulatory issues. Although support for early-stage projects would generally be most beneficial, support for later-stage projects (RTR or FOAK reactor projects) can support projects at a key stage of deployment and reduce the burden on applicants. Support for these different levels of project maturity could be based on the DOE-NE priorities for advanced nuclear energy development, demonstration, and deployment activities.

IV. Applicability of Licensing Interaction

The applicability of the licensing interaction is a characteristic that can be useful when discussing licensing cost-share grant proposals. The scope for an applicants' interactions with the NRC can be generally characterized based on the narrow to general applicability of an interaction:

- Applicability of licensing interaction (increasing level of specificity)
    - Generally applicable topic
    - Technology-specific topic
    - Design-specific topic
    - License-specific topic

In general, it would be advisable to prioritize support of licensing interactions with more general applicability. Advanced reactors will have a variety of different licensing topics or questions that may require extended regulatory interactions to resolve including policy questions, analysis method questions, or questions related to availability and quality of technical data to support regulatory decisions. Prioritizing topics that are generally applicable to advanced reactors (e.g., co-siting of advanced reactors with industrial facilities) or applicable across an advanced technology category (e.g., fuel qualification for reprocessed fuel forms) help maximize the use of the Advanced Nuclear Energy Cost-Share Grant Program funding to create regulatory decisions applicable to multiple developers.

There are cases, however, where support of projects with applicability to a specific design or license may have substantial benefits. Supporting licensing interactions on the design features for a specific research and test reactor could help accelerate reactor deployment and generation of engineering and technical data useful to advanced reactor development more broadly. Supporting licensing interactions for novel advanced reactor designs or projects could help demonstrate new use cases or business models that otherwise do not have specific regulatory or policy questions. These specific projects could have cross-cutting benefits and support DOE-NE's broader development, demonstration, and deployment objectives.

V. Topic of Licensing Interaction:

The topic type of the licensing interaction is the final characteristic that can be useful when discussing licensing cost-share grant proposals. Like the applicability of a license interaction, the topic for an applicants' interactions with the NRC can be generally characterized based on the narrow to general relevance of the topical area:

- Topic of licensing interaction (increasing level of specificity)
    - Policy question
    - Programmatic or implementation question
    - Regulatory interpretation question
    - Design method question
    - Analysis method question
    - Technical data question
    - Operational program question
    - Design feature question

Similar to the applicability of the licensing interactions, it would also be advisable to prioritize support of licensing interaction topics that are more general. The first three licensing interaction topics (policy question, programmatic or implementation question, regulatory interpretation question) are important to address because they are both relevant to a wide range of advanced reactor developers and projects and they can have a significant impact on the fundamental design, business case, and licensing strategy for projects. Topics that represent a change from existing policy (e.g., emergency planning zone requirements, reactor operator requirements) or address new questions (e.g., transportable nuclear reactors, autonomous control of nuclear reactors) could be extremely valuable to support because they will address longer-term questions that decisions by developers and energy users. This could ensure that the projects supported by Advanced Nuclear Energy Cost-Share Grant Program are addressing longer term questions relevant to multiple stakeholders.

The fourth and fifth licensing interaction topics (design method question, analysis method question) are particularly impactful for advanced reactor developers because they can provide the regulatory certainty on the ways that advanced reactor developers are designing or licensing their technologies. The topics may focus on a specific design feature (e.g., use of functional containment) or an analysis method (e.g., maximum credible accident, identification of initiating events) that are applicable to a small number of technologies (e.g., technologies with identical characteristics such as power level, fuel, and coolant) or larger number of technologies (e.g., technologies of with a small number of similar characteristics such as power level) based on the specific topic. These topics may also be addressed generically or specifically, and special consideration could be given to topics that enable applicability more generically rather than less generically.

The final three licensing interaction topics (technical data question, operational program question, design feature question) are typically applicable for a specific design or application. Supporting licensing interactions for a specific research and test reactor could help accelerate reactor deployment and generation of technical data useful to advanced reactor development more broadly or demonstration of programs and design features that could be applicable to future advanced reactor developers. Supporting licensing interactions for topics that support novel advanced reactor designs or projects could help demonstrate new use cases or business models. Addressing these questions could have cross-cutting benefits and support DOE-NE's broader development, demonstration, and deployment objectives.

VI. Project Examples

Specific projects that could be used as examples of topics that could be valuable for the Advanced Nuclear Energy Cost-Share Grant Program to support include:

- Simplified licensing approaches for commercial microreactors
    - Some advanced reactor technologies may be able to utilize licensing analysis methods simpler than used for conventional nuclear technology. This change could reduce the time and cost associated with new reactor licensing. These analyses may require exemptions from existing regulatory requirements and NRC staff acceptance of alternative methodologies. Pre-application interactions and supplementary submission reviews that increase alignment and answer questions relevant to the use of new licensing approaches for advanced reactors.
- Transportation of fully-fueled reactors
    - Some advanced reactor concepts (typically factory constructed microreactors) have proposed transportation of fully-fueled reactors to sites for installation. This new approach could reduce the time and cost associated with construction and enable the factory standardization of fueling, testing, maintenance, and defueling. However, this would require addressing technical, policy, and programmatic questions and barriers. Pre-application interactions and supplementary submission reviews that address the policy and technical gaps could help facilitate the licensing of this class of reactors.
- Fuel qualification for molten salt reactors
    - Fuel qualification for conventional reactor fuel has typically relied on the testing and analysis of solid fuels to demonstrate performance and safety characteristics. The fuel qualification for molten fuel forms does not have clear regulatory requirement analogs so there may be questions on how to address implementation questions. Pre-application interactions and supplementary submission reviews related to addressing fuel qualification guidance and technical gaps could help facilitate the licensing of this class of reactors.
- Co-siting or integration of nuclear reactors with industrial energy users
    - Some advanced reactor concepts have use cases that enable use of reactor outputs (e.g., high temperatures process fluids, steam) in industrial energy

applications. Both the interfaces between advanced reactors and industrial applications and the co-siting of advanced reactors and industrial facilities could introduce new regulatory and technical questions. Pre-application interactions and supplementary submission reviews related to addressing regulatory questions, guidance, and technical gaps could help facilitate licensing.

- Alternative environmental evaluations for reactor licensing
    - Existing regulations for nuclear reactors require that all commercial fission reactors complete an Environmental Impact Statement as part of the licensing process. Some advanced reactors concepts may have an environmental or safety case that could enable the use of alternative environmental evaluations such as Environmental Assessments or Categorical Exclusions. These processes are not currently permitted by regulation, so addressing these questions through pre-application interactions and supplementary submission reviews could help facilitate licensing using novel regulatory processes.
- Remote operation of nuclear reactors
    - Current requirements for nuclear reactors do not permit the remote operation of reactors. Some microreactor concepts with off-grid applications rely on remote operation to help support the economic and operational business case. Remote operation would have a large variety of regulatory, policy, methodological, and technical questions. Addressing these questions through supplement submission reviews would be critical to enabling these business and operational paradigms.
- Autonomous or semi-autonomous operation of nuclear reactors
    - Current requirements for nuclear reactors require human operators to make operational and control decisions. Some advanced reactor concepts (e.g., those relying on reduced human operator intervention as part of their safety or economic operational case) would benefit significantly from full autonomous or semi-autonomous operation. This mode of operation would have a large variety of regulatory, policy, methodological, and technical questions. Addressing these questions through supplement submission reviews would be critical to enabling these operational modes.
- Definition of performance-based surrogate licensing criteria for advanced reactors
    - Conventional nuclear reactors have historically used performance surrogates such as a core damage frequency (CDF) and large early release frequency (LERF) to help assess compliance with quantitative health objectives (QHOs) and changes in plant risk during operation and maintenance (e.g., change in CDF). These performance-based surrogate licensing criteria may not be applicable or accurate for some advanced reactor technologies so new criteria may be needed to support licensing. Supporting the development of criteria and addressing underlying regulatory questions through supplement submission reviews would be critical to developing effective safety cases for some advanced reactors.
- Benchmarked power ascension testing of novel advanced reactors

    - Some novel advanced reactors may have sufficiently novel design features or operational characteristics that a comprehensive demonstration of safety by analysis or testing is infeasible or impracticable. As a result, use of a benchmark power ascension testing program may be useful to help confirm the analytic basis for a plant while limiting plant risk. This power ascension process is not yet well characterized by existing NRC regulation or guidance, so addressing technical and regulatory questions would be critical to support this licensing pathway. Supporting NRC review of supplement submission reviews would be critical to establishing this licensing pathway for advanced reactors.
- Additional safety features for prototype licensed reactors and subsequent removal
    - The prototype reactor licensing process is potentially a valuable process to facilitate efficient licensing of novel advanced reactor designs. This process enables the use of "additional safety features to protect the public and the plant staff from the possible consequences of accidents during the testing period" and account for uncertainties in the licensed design. This process could support the accelerated licensing of novel advanced reactors but would require a better policy and regulatory framework for the use (and subsequent removal) of the additional safety features on a prototype reactor. Supporting NRC review of supplement submission reviews that address policy and regulatory questions would be critical to establishing this licensing pathway for advanced reactors.
- Preapplication discussions on licensing strategy for novel advanced reactors
    - Some novel advanced reactors applicants may seek to utilize novel licensing strategies different from those currently imagined for applications. This type of regulatory innovation could be supported as it may provide lessons learned or new regulatory pathways for future advanced reactor applicants. Preliminary evaluation of proposed licensing strategies should be conducted to ensure that the pathways are at least a plausible change from existing practice. Addressing policy and regulatory processes questions through supplement submission reviews would be critical to enabling these new pathways.
- Preapplication interactions for new advanced reactor license applicants (e.g., communities, industrial heat users)
    - Some advanced reactor applicants may have limited experience with the licensing of new nuclear power plants. Specifically, some advanced reactor applicants may be communities or industrial heat users that have not historically licensed, owned, or operated nuclear power plants. This experience gap can represent a barrier to licensees that could derive significant benefits if they can effectively navigate the licensing process. Support for applicants that represent new users, communities, or applications could provide invaluable lessons learned for subsequent applicants. This includes pre-application interactions and supplementary submission reviews for a wide variety of licensing activities that help facilitate and accelerate licensing for new applicants.