APPROACHES FOR EXPEDITING AND ESTABLISHING STAGES IN THE LICENSING PROCESS FOR COMMERCIAL ADVANCED NUCLEAR REACTORS

A Report for the
Senate Committee on Environment and Public Works and the
House Committee on Energy and Commerce

By the U.S. Nuclear Regulatory Commission

Enclosure 1

INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) developed this report as required by Section 103(b) of the Nuclear Energy Innovation and Modernization Act (NEIMA), which requires the NRC to submit to the appropriate congressional committees a report for expediting and establishing stages in the licensing process for commercial advanced nuclear reactors that will allow implementation of the licensing process by not later than two years after the Act's enactment. Section 103(b) includes requirements for coordination and seeking stakeholder input, providing cost and schedule estimates, and evaluating various policy and technical issues associated with advanced nuclear reactor technologies. The NRC has addressed each of these requirements and organized this report to group related topics.

The NRC is an independent regulatory agency. The NRC's mission is to license and regulate the Nation's civilian use of radioactive materials to provide reasonable assurance of adequate protection of public health and safety, to promote the common defense and security, and to protect the environment. The U.S. Department of Energy's (DOE's) mission is to ensure the Nation's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions. The NRC and DOE have been working together as the NRC prepares to review and regulate a new generation of non-light-water reactors. For this report, the NRC has focused on light-water small modular reactors (SMRs); non-light-water reactors (non-LWRs), including high-temperature gas-cooled reactors (HTGRs), liquid-metal fast reactors (e.g., sodium-cooled fast reactors (SFRs)), and molten salt reactors (MSRs); and micro-reactors. The NRC and the DOE Office of Science/Fusion Energy Sciences have initiated routine interactions to develop longer-term strategies for the possible deployment of fusion reactors. Many of the regulatory changes being considered for non-LWRs will inform strategies for licensing fusion reactors.

BACKGROUND

The NRC has interacted with developers in several pre-licensing activities and developed policies, processes, and guidance to support the potential licensing of advanced nuclear reactors. The NRC's Policy Statement on the Regulation of Advanced Reactors was first issued on July 8, 1986 (51 FR 24643) (Ref. 1), with an objective to provide all interested parties, including the public, with the Commission's views concerning the desired characteristics of advanced reactor designs. The policy statement identifies attributes that should be considered in advanced designs, including highly reliable and less complex heat removal systems, longer time constants before reaching safety system challenges, reduced potential for severe accidents and their consequences, and use of the defense-in-depth philosophy of maintaining multiple barriers against radiation release. In the policy statement, the Commission also encouraged the earliest possible interaction between applicants, vendors, and other government agencies and the NRC to provide for early identification of regulatory requirements for advanced reactors and to provide all interested parties, including the public, with a timely, independent assessment of the safety and security characteristics of advanced reactor designs to add stability and predictability in the licensing and regulation of advanced reactors.

Following the issuance of the advanced reactor policy statement in 1986, the NRC interacted with DOE and reactor developers regarding the potential licensing of advanced reactor designs for which design information was provided in the form of a Preliminary Safety Information Document. These activities resulted in the publication of assessments of preliminary designs such as NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor

Innovative Small Module (PRISM) Liquid-Metal Reactor" (Ref. 2); and NUREG-1338, "Draft Preapplication Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor [MHTGR]" (Ref. 3). The NRC staff identified several potential policy issues during its assessments of advanced reactor designs, and proposed approaches to resolve some of the policy issues in SECY-93-092, "Issues Pertaining to the Advanced Reactor (PRISM, MHTGR, and PIUS [Process Inherent Ultimate Safety]) and CANDU 3 [Canadian Deuterium Uranium] Designs and Their Relationship to Current Regulatory Requirements" (Ref. 4). The Commission approved the NRC staff's proposed approaches in a Staff Requirements Memorandum (SRM) dated July 30, 1993 (Ref. 5).

During the 1990s, the NRC continued to develop licensing approaches for advanced reactors. These activities were done in parallel with, and sometimes interwoven with, the NRC's efforts to improve risk-informed and performance-based approaches within the agency (e.g., the Commission's Policy Statement, "Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities," published on August 16, 1995 (60 FR 42622) (Ref. 6)). The Commission provided further clarification in the white paper "Risk-Informed and Performance-Based Regulation," dated March 1, 1999 (Ref. 7). In the early 2000s, the NRC continued to identify and resolve policy and technical issues during preapplication activities on advanced reactor designs, including the Gas Turbine Modular Helium Reactor and Pebble Bed Modular Reactor. In August 2008, the NRC and DOE jointly issued a report to Congress, "Next Generation Nuclear Plant (NGNP) Licensing Strategy" (Ref. 8). The NRC staff continued activities related to advanced reactors following the specific work related to the NGNP. In August 2012, the NRC published its strategy for and approach to preparing for the licensing of advanced reactors in its "Report to Congress, Advanced Reactor Licensing" (Ref. 9).

In 2016, the NRC issued its "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light-Water Mission Readiness" (Advanced Reactor Vision and Strategy Document) (Ref. 10), in response to increasing interest in advanced reactor designs. The NRC issued this document in the same timeframe as DOE issued its "Vision and Strategy for the Development and Deployment of Advanced Reactors" (Ref. 11). The NRC considered DOE's advanced reactor deployment goals when setting priorities for its readiness activities.

To achieve the goals and objectives stated in the Advanced Reactor Vision and Strategy Document, the NRC staff developed implementation action plans (IAPs). The IAPs identified the specific activities that the NRC staff planned to conduct in the near-term (within 5 years), mid-term (5 to 10 years), and long-term (beyond 10 years) timeframes. The NRC staff released its draft IAPs to obtain stakeholder feedback during a series of public meetings held between October 2016 and March 2017. The NRC staff also briefed the Advisory Committee on Reactor Safeguards (ACRS) on March 8 and 9, 2017. The NRC staff considered the ACRS comments and stakeholder feedback in the final Near-Term IAPs (Ref. 12) and Mid-Term and Long-Term IAPs (Ref. 13), issued on July 12, 2017.

The near-term IAPs address six individual strategies:

(1) Acquire/develop sufficient knowledge, technical skills, and capacity to perform non-LWR regulatory reviews.

(2) Acquire/develop sufficient computer codes and tools to perform non-LWR regulatory reviews.

(3) Develop guidance for a flexible non-LWR regulatory review process within the bounds of existing regulations, including the use of conceptual design reviews and staged-review processes.

(4) Facilitate industry codes and standards needed to support the non-LWR life cycle (including fuels and materials).

(5) Identify and resolve technology-inclusive policy issues (those not specific to a particular non-LWR design or category) that impact regulatory reviews, siting, permitting, and/or licensing of non-LWR nuclear power plants.

(6) Develop and implement a structured, integrated strategy to communicate with internal and external stakeholders having interests in non-LWR technologies.

Based on input received from stakeholders on the draft near-term IAPs and ACRS recommendations, the NRC staff assigned priority to its execution of Strategies 3 and 5; however, activities are ongoing in support of all six strategies. The NRC staff issued “Advanced Reactor Program Status,” (SECY-19-0009) on January 17, 2019 (Ref. 14). This document provides the status of the NRC staff's activities related to advanced reactors, including the progress and path forward on each of the IAP strategies. It also provides an overview of the various external factors influencing the NRC staff's activities to prepare for licensing and deployment of advanced reactors. Activities identified in the Advanced Reactor Vision and Strategy Document for ensuring NRC processes support a staged licensing approach were expedited and among the first items completed under Strategy 3 of the IAPs.

UNIQUE ASPECTS OF COMMERCIAL ADVANCED NUCLEAR REACTOR LICENSING (Sec. 103(b)(4)(A)(i))

NEIMA defines “advanced nuclear reactor” as a nuclear fission or fusion reactor, including a prototype plant, with significant improvements compared to commercial nuclear reactors under construction as of the date of enactment of the Act. This definition therefore includes light-water SMR designs like NuScale, non-LWR designs such as X-Energy, LLC’s Xe-100 reactor and Kairos Power LLC’s fluoride-salt-cooled high-temperature reactor (FHR), and micro-reactor designs such as Oklo Inc.’s compact fast reactor and the Westinghouse eVinci micro-reactor. Over the past several years, there has been significant interest in the development and licensing of advanced reactors that will be very different from the large LWRs that are currently used to generate electricity in the United States. For example, some advanced reactors will use gas, liquid metal, or molten salt as a coolant and are expected to provide enhanced margins of safety and/or use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions. Some will have a fast neutron spectrum (LWRs have a thermal neutron spectrum), some will operate at or near atmospheric pressure, and some will be much smaller than current generation LWRs. The application of these reactors is for electricity or possibly for process heat, research and testing, isotope generation, or space applications. The unique aspects associated with these designs influence the basic approaches to the safety functions of controlling reactivity, removing heat from the reactor and waste stores, and limiting the release of radioactive material for a design. These unique aspects have been considered in the development of the Advanced Reactor Vision and Strategy Document and implementation of associated readiness activities, including pursuing changes to the NRC’s regulatory requirements (e.g., emergency preparedness and security) and licensing processes.

COORDINATION AND STAKEHOLDER INPUT (Sec. 103(b)(2))

The NRC staff coordinated with DOE and other stakeholders in developing this report. Specifically, the NRC discussed plans for preparation of this report with DOE representatives on March 19, 2019, and sought DOE input on the draft report. The NRC also discussed plans for preparation of this report during a public meeting on March 28, 2019, to seek input from advanced reactor stakeholders, including the nuclear energy industry, a diverse set of technology developers, DOE, and other public stakeholders. DOE and other stakeholders noted that the NRC has appropriately identified ongoing and completed non-LWR readiness activities that are responsive to NEIMA. They also recommended that the NRC continue to implement the Advanced Reactor Vision and Strategy Document and IAPs to achieve the agency's overarching strategic goals and objectives, including assuring readiness to effectively and efficiently review and regulate advanced reactors. The NRC will continue to interact with DOE and other stakeholders to gather information that will inform the NRC's advanced reactor readiness activities.

Since July 2016, the NRC has conducted about 30 public stakeholder meetings to discuss advanced reactor topics of interest, including staged licensing, fuel qualification, and consensus codes and standards. To maximize participation, stakeholders can participate in person or by phone and webinar. Additional examples of stakeholder engagement include a series of three advanced reactor workshops that were co-hosted by the NRC and DOE in 2015, 2016, and 2017, and advanced reactor sessions that were conducted at the NRC's annual Regulatory Information Conference. The NRC has also conducted several public briefings of the ACRS Future Plant Subcommittee and ACRS full committee. The NRC staff will continue to conduct public meetings with stakeholders approximately every 6 weeks. The NRC staff also has routine public meetings with developers of specific advanced reactor designs, including NuScale, Oklo, X-Energy, and Kairos, related to specific designs and licensing issues. The NRC and DOE Office of Science/Fusion Energy Sciences have initiated routine interactions to inform the NRC staff and develop longer-term strategies for the possible deployment of fusion reactors.

LICENSING COMMERCIAL ADVANCED NUCLEAR REACTORS UNDER THE EXISTING REGULATIONS (Sec. 103(b)(4)(B)), INCLUDING USE OF LICENSING PROJECT PLANS (Sec. 103(b)(4)(B)(i))

The NRC is fully capable of reviewing and making a safety, security, or environmental finding if an advanced reactor application were to be submitted today. The agency has acknowledged that the efficiency of existing processes and requirements could be improved. Therefore, the NRC staff developed its Advanced Reactor Vision and Strategy Document and IAPs. The NRC staff has made significant progress in developing risk-informed and performance-based licensing strategies under the current regulations in support of IAP Strategy 3, as discussed in more detail in the NRC's report entitled "Increasing the Use of Risk-Informed and Performance-Based Evaluation Techniques and Regulatory Guidance in Licensing Commercial Advanced Nuclear Reactors."

The NRC staff also developed design criteria for advanced reactors, under IAP Strategy 3, as an important step in providing stakeholders with insights on how the NRC staff views the unique characteristics of advanced reactor technologies. In 2013, the NRC, in coordination with DOE, began work on an initiative to develop guidance for principal design criteria (PDCs) for non-LWRs. The purpose of the initiative was to assess the general design criteria (GDCs) in the current regulations to determine to what extent they apply to non-LWR designs and, if not, to propose PDCs that address non-LWR design features while recognizing that the underlying safety objective of each GDC still applies.

After reviewing a proposed set of design criteria prepared by DOE, the NRC developed design criteria for non-LWRs and issued Draft Regulatory Guide DG-1330, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors" (Ref. 15), for public comment on February 3, 2017. After significant stakeholder interaction, the NRC staff published final Regulatory Guide (RG) 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors," on April 3, 2018 (Ref. 16). RG 1.232 provides guidance to reactor designers, applicants, and licensees of non-LWR designs on developing PDCs for any non-LWR design subject to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 17), and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 18).

Regulatory Review Roadmap and Licensing Project Plans

The NRC has a variety of options for performing regulatory reviews of new designs for nuclear power plants. Understanding what options are available and how to choose the best option at any given stage may be difficult for a designer, especially one that is less familiar with the NRC's regulatory framework and associated review processes. Therefore, the NRC staff developed guidance under IAP Strategy 3 to highlight the flexible and staged regulatory mechanisms and licensing processes available within the bounds of existing regulations. Those options include review of a complete design in an application for a permit, license, or certification; review of a partial design in a standard design approval (SDA) application or topical report; and feedback related to preapplication information.

The NRC staff evaluated the Nuclear Innovation Alliance (NIA) report, "Enabling Nuclear Innovation Strategies for Advanced Reactor Licensing," dated April 2016 (Ref. 19), and adopted the report's recommendations after interactions with stakeholders to develop "A Regulatory Review Roadmap for Non-Light Water Reactors," in December 2017 (the Roadmap) (Ref. 20). The Roadmap provides guidance for a flexible licensing process within the bounds of existing regulations, including the use of conceptual design reviews and staged licensing processes. The NRC made a draft version of the Roadmap available to the public, and it was the subject of discussions during routine public meetings with DOE and stakeholders. The Roadmap provides advanced reactor designers with a clear overview of the options available for NRC review of preapplication information and of formal applications, helps define processes and interactions for various stages of the design and licensing process, and standardizes terminology and expectations. It describes multiple regulatory processes reflecting design development activities and appropriate interactions between the NRC staff and stakeholders at various stages of the reactor design process. In addition, Enclosure 1 to the Roadmap describes testing needs and prototype plants. Testing can be done at various stages of the design process and is an important part of the Roadmap that a designer should consider early in the design process.

The Roadmap is also intended to help designers prepare technology- or design-specific licensing project plans.[1] A licensing project plan describes a potential applicant's plan to engage with the NRC during the development and review of an application for a license, certification, or approval and helps define the roles and responsibilities between the NRC and

[1] The Roadmap uses the terminology "regulatory engagement plans" in lieu of "licensing project plans" consistent with the terminology used by most advanced reactor designers. The term "licensing project plan" is used throughout this report, consistent with the terminology used in NEIMA.

the applicant at the onset of regulatory interactions. Such a plan defines desired outcomes for the various interactions between the designer and the NRC, considering factors such as the technology readiness level of the reactor design, the resources available to the designer and the NRC, and the coordination of the review with the resolution of any related regulatory issues and other aspects of the overall program for developing and deploying advanced reactor designs. Technology- or design-specific licensing project plans can be developed in cooperation with groups or individual designers to align the regulatory review plan with other plans, including research and development (R&D). Characterization of design or technology status will be a key aspect of aligning the design, research, and regulatory processes.

The development of the licensing project plan will include interactions with the NRC staff to reach agreement on the desired outcomes of defined interactions and estimated costs and schedules for defined reviews. The licensing project plan is expected to establish milestones that correspond to stages of a licensing process for a specific advanced reactor project and focus on near-term activities. Longer-term licensing and construction strategies for commercial units can be useful to include in the licensing project plan to align the licensing processes with R&D activities, business models, and the resolution of associated public policy matters. However, uncertainties in these areas need not prevent interactions and progress on near-term activities related to the selection of key design alternatives and the development of a preliminary design. In June 2018, the Nuclear Energy Institute (NEI) issued NEI 18-06, "Guidelines for Development of a Regulatory Engagement Plan" (Ref. 21), which suggests topics for a prospective applicant to consider in developing the scope and content of a licensing project plan. While the NRC was not requested to endorse NEI 18-06, the NRC staff is familiar with the contents and concluded that it includes guidance that could be beneficial to applicants.

The NRC staff has received several licensing project plans from reactor developers and has used them to develop associated NRC review plans and establish expectations in terms of outcomes, resources, and schedules for specific interactions. Periodic project management meetings are conducted during the preapplication and licensing processes to monitor project progress and costs.

In sum, the NRC has established procedures and processes for preparing and implementing licensing project plans, and applicants are following these procedures and processes.

TOOLS TO INTRODUCE STAGES INTO THE LICENSING PROCESS (Sec. 103(b)(4)(B)(ii))

The Roadmap describes flexible licensing processes available to developers and the NRC, including interactions during the conceptual design phase, preliminary design phase, and SDAs, to define possible staged reviews for designs or parts of designs at various levels of completion or maturity (i.e., across a spectrum of technology readiness levels). The Roadmap provides guidance to potential applicants within the bounds of existing NRC regulations for licenses, certifications, and approvals, as described in the licensing processes in 10 CFR Part 50 and 10 CFR Part 52, and describes how licensing mechanisms can be used as tools to introduce stages into the licensing process. Licensing project plans and associated NRC review plans are used to establish expectations in terms of outcomes, resources, and schedules to reach agreement on the desired outcomes of defined interactions.

In addition to formal regulatory applications, preapplication interactions and preparation of supporting reference documents, while voluntary, are intended to help ensure that potential applications for licenses, certifications, and approvals are in accordance with the NRC's regulations. Plans for the overall deployment of advanced reactor designs might include multiple projects and different licensing approaches for related research and test reactors, first-of-a-kind large-scale plants, and subsequent commercial plants. Previous preapplication interactions highlight the importance of regulatory feedback in areas such as fundamental safety approaches, research, qualification of materials and fuels, and plans for integral and systems tests.

The NRC staff included an introductory section in the standard review plans for LWRs specifically related to preapplication activities for light-water SMRs. Consistent with this guidance, the NRC staff has been engaged in significant preapplication interactions with SMR vendors on a variety of topics. Building on recent experience with LWRs and past experience with advanced reactors, the NRC staff developed the Roadmap to help developers prepare licensing project plans, and the NRC is working on other contributing activities to ensure regulatory requirements are commensurate with risks from advanced reactor technologies.

The alignment of regulatory interactions with the stages of development of advanced reactor designs is supported by technology- or design-specific licensing project plans that reflect the results of technology- or design-specific assessments, such as phenomenon identification ranking tables or technology readiness level evaluations (at the technology, plant and/or structure, system, or component (SSC) level); the status of supporting research and testing; and the prioritization of desired feedback from the NRC. The NRC staff and the applicant would come to agreement on the appropriate levels of review and possible forms of feedback (e.g., verbal exchange, written correspondence, and/or safety evaluation), considering available resources within the NRC and from the applicant, the schedule, and the importance of the issue. Aspects of the overall project plan dealing with the designer's business model, as well as some public policy issues, may influence the priorities and schedules proposed by a designer but are not directly related to the NRC's regulatory review and licensing processes.

The NRC concludes that it has established mechanisms to introduce stages into the licensing process, and applicants are already making use of those mechanisms. The following sections provide additional discussion of details of these mechanisms. As in preapplication interactions, the licensing project plan and associated NRC review plans should establish expectations in terms of outcomes, resources, and schedules. Periodic project management meetings will be conducted during the topical report review or SDA process to monitor project progress and costs.

<u>Topical Reports</u>

A prospective applicant may, at its option, submit topical reports for NRC review. The NRC sponsors a topical report program to increase the efficiency of the licensing process and reduce the burden on applicants and licensees. A topical report is a standalone report containing technical information about a reactor, SSC, or safety topic that can be submitted to the NRC for its review and approval. Topical reports improve the efficiency of the licensing process and have traditionally been used to obtain NRC staff approval for the design of key SSCs, methodologies, computer codes and models, operational requirements, or other subjects for subsequent referencing in licensing applications. An NRC-approved topical report can provide a technical basis for a licensing action and regulatory certainty on key concepts in advance of an application. Topical reports have been used extensively in the review of LWR designs and are expected to be an important vehicle for obtaining NRC staff findings (conditional or conclusive) on proposed design features and analysis methodologies for advanced reactor designs. Topical reports can be a valuable tool to obtain early NRC staff review and approval of certain aspects of an advanced reactor design in support of staged licensing approaches.

Standard Design Approval

The NRC issues SDAs under 10 CFR 52.143, "Staff Approval of Design." To obtain an SDA, a designer may submit either the final design for the entire facility or the final design of major portions of the facility. Like a Design Certification (DC) rulemaking, the SDA documents the NRC staff's conclusive findings; however, an SDA does not provide finality in that issues resolved in the SDA may be reconsidered during a rulemaking for a subsequent DC or during hearings associated with a construction permit or combined license application referencing the SDA. An SDA can nevertheless be a useful tool within a licensing project plan, in combination with preapplication interactions held during the conceptual and preliminary design processes. The SDA and the related safety evaluation report document NRC staff findings, involve ACRS reviews, and can be referenced in subsequent license applications. The SDA and the related safety evaluation report must be relied upon by the ACRS and the NRC staff in any review of a license application that references the SDA unless significant new information substantially affects the staff's safety evaluation report. As such, the SDA can provide incremental progress towards the licensing or certification of an advanced reactor design, thereby introducing stages in the licensing process. An applicant for a construction permit or combined license may reference an SDA for those portions of the plant included in the scope of the SDA.

A potentially useful feature of an SDA is that its scope includes the design of a nuclear power plant or major portions thereof. This differs from the scope of a DC, which consists of an essentially complete nuclear power plant design. The ability to limit the scope of an SDA to major portions of a design provides an opportunity for regulatory interactions to focus on those plant features most related to controlling the risks to public health and safety or those plant features whose design has been finalized under a staged design and licensing strategy. Power conversion systems or other plant features may either remain in a conceptual or preliminary design process or not be included in information provided for NRC staff review. Defining a major portion of a design for an SDA may be challenging given the relationships between various plant systems and the contributions of all systems to plant risk. Licensing project plans and other interactions between a designer and the NRC staff should include a rationale for which portion(s) of a plant will be included in the application and which can be excluded from the review or addressed though concepts like the "conceptual design information" or "design acceptance criteria" used for some DCs.

Advanced reactor developers considering seeking an SDA may find additional insights in the NIA report, "Clarifying 'Major Portions' of a Reactor Design in Support of a Standard Design Approval" (Ref. 22), which is referenced in the Roadmap. The NRC staff provided feedback on this report on July 20, 2017 (Ref. 23).

CONCEPTUAL DESIGN ASSESSMENTS (Sec. 103(b)(4)(B)(v))

The NRC has in place a process for conceptual and preliminary design assessments. The Roadmap uses the term "conceptual design process" to refer to early consideration and selection of various key alternatives that will define the fundamental design features and general principles of operation. These decisions involve matters such as basic approaches to the safety functions of controlling reactivity, removing heat from the reactor and waste stores, and limiting the release of radioactive material. The selection of these design features helps define research and testing programs, appropriate safety analyses, associated fuel cycle and public policy issues, and other matters to be resolved in later phases of the design. The conceptual design phase supports the development of a licensing project plan, including identifying those matters that should involve early regulatory interactions to support coordination with other aspects of the overall project. The licensing project plan and the associated NRC review plan should define the expected outcomes from early interactions (e.g., initial feedback, conditional NRC staff finding, conclusive NRC staff finding, or final agency position) and related matters such as costs, schedules, and research plans.

The NRC staff has previously interacted with advanced reactor designers during the conceptual design process and provided initial feedback on possible design approaches to fulfill fundamental safety functions. During these interactions, the NRC staff has also identified technical and policy issues and worked to develop and issue final agency positions related to these issues, providing advanced reactor designers with additional confidence in selecting design alternatives. The NRC's ongoing assessment of possible changes to emergency planning requirements for light-water SMRs and other new technologies, including non-LWRs, is an example of such activities (Ref. 24).

The NRC staff foresees maintaining this flexible approach for future interactions with advanced reactor designers such that the NRC review plans will identify key topics, associated interactions, and outcome goals. These interactions support the designers' abilities to assess alternatives and progress through design phases. As previously discussed, available resources may limit the ability of designers to develop and execute plans for regulatory engagement during the conceptual design process. These limitations may, therefore, require prioritization of key topics and could affect expected regulatory outcomes.

As the design process progresses from conceptual to the preliminary design phase, research, analyses, and other activities support more detailed design decisions and verification of the design performance in terms of commercial targets and safety requirements. At the preliminary design stage, documents may be provided to the NRC for information or to solicit feedback on testing programs, safety analysis approaches, or the overall feasibility of licensing a design. The preliminary design documents and related NRC reviews in the late 1980s and early 1990s involved essentially complete plant designs with regard to the scope of the design and the level of design detail. Some previous non-LWR preapplication submittals have focused more on specific design features or portions of the design (e.g., fuel design).

The preapplication safety evaluation reports prepared in the 1990s for liquid-metal and gas-cooled reactor preliminary designs helped the NRC identify and develop the regulatory framework to review non-LWR designs. These reports also provided confidence to designers in the feasibility of licensing the specific designs. Although circumstances led to those projects being deferred, the NRC's interactions with DOE and the designers identified valuable insights on safety features, R&D programs, and proposed testing needs. Although the NRC reviews did not result in an approval of the designs because of project termination, it was expected that the preapplication efforts would help inform future licensing submittals. The NRC staff was able to conclude, at that time, that its reviews had identified no obvious impediments to licensing those designs. The appropriate use of the various interactions and tools described above can support a long-term program for the design and deployment of a non-LWR while potentially minimizing the additional review efforts needed to reach conclusive findings or final agency positions during different parts of the subsequent review and approval process. Preliminary design reviews and other tools can help designers, DOE, and other stakeholders determine whether design and testing programs for a non-LWR will support the eventual approval, certification, or licensing of a plant. The scope of the NRC's review findings will be dependent on the design maturity and the completeness of the submittals.

For preapplication design interactions where there is a high degree of design completeness, such as the preapplication safety evaluation reports issued by the NRC in the 1990s, a preliminary design review could result in a statement that the NRC has identified no obvious impediments to the licensing of the specific design or major parts of the design provided for review. For preliminary designs with less maturity, the NRC evaluation of the design would have a commensurate, and likely reduced, degree of regulatory certainty. If the NRC does identify impediments to licensing during the preliminary design review, that feedback will also be valuable to the potential applicant.

COST AND SCHEDULE ESTIMATES (Sec. 103(b)(3))

As discussed in the Advanced Reactor Vision and Strategy Document and IAPs, the NRC plans to achieve its overarching advanced reactor readiness strategic goals and objectives by no later than 2025, including assuring readiness to effectively and efficiently review and regulate advanced reactors. However, to support potential near-term applications, the NRC expedited and completed certain readiness activities, including those related to staged licensing processes. Through the issuance of the Roadmap, which provides guidance to potential applicants on developing licensing project plans, the NRC has completed all readiness activities necessary to implement strategies to establish stages in the licensing process for commercial advanced nuclear reactors, as required by NEIMA. The cost of these activities was funded through the non-fee-recoverable appropriations for advanced reactor regulatory infrastructure activities.

IDENTIFICATION OF POLICIES AND GUIDANCE FOR NRC STAFF (Sec. 103(b)(4)(B)(vi))

The NRC has not identified any policies or guidance that is specifically needed to implement licensing project plans or the tools described in Section 103(b)(4)(B)(ii) of NEIMA. The NRC guidance contained in the Roadmap and the industry guidance contained in NEI 18-06 describe how a licensing project plan can define the licensing mechanisms that would be used as tools to introduce stages into the licensing process for an applicant's specific advanced reactor design.

IMPROVING EFFICIENCY, TIMELINESS, AND COST-EFFECTIVENESS OF LICENSING REVIEWS (Sec. 103(b)(4)(C))

The NRC's strategic goal of the Advanced Reactor Vision and Strategy Document is to assure NRC readiness in all aspects of regulatory operations needed to efficiently and effectively review and regulate advanced reactors. Frequently asked questions about the preapplication and application review processes relate to the costs of NRC reviews and the NRC's ability to provide timely regulatory feedback. To minimize the delays that may result from any necessary amendment or supplement to an application, the NRC will continue to work with advanced reactor developers to establish mutually agreeable review plans that include a defined scope and level of review, desired outcome in terms of regulatory observations, areas of focus, review costs, and review schedules. The NRC staff will arrange meetings throughout the process to support the review, to ensure the goals of the review plan are being met and to monitor costs and schedules.

The agency is implementing a small "core review team" approach to support a more cost-effective evaluation of non-LWR design applications. The core review team concept provides stability and consistency to the developer while ensuring efficient use of available NRC resources. This is particularly important when designs include innovative features, different physical phenomena, potentially revised and new design basis events, and significant technical and policy issues. The multi-disciplinary core review team serves to identify system interactions; risk significant issues; relationships between the responses to design-basis, design extension, and beyond-design-basis events; and other matters. The formation of a multi-disciplinary core review team reduces the needed training and involvement of a larger number of NRC staff in the review of advanced reactor designs.

The NRC has been successfully implementing all of these approaches during the on-going preapplication engagements with Oklo, Kairos Power, and X-energy, and plans to continue to implement these approaches with future applicants and potential applicants.

IMPROVING THE PREDICTABILITY OF THE COMMERCIAL ADVANCED NUCLEAR REACTOR LICENSING PROCESS (Sec. 103(b)(4)(D))

To enhance regulatory predictability and stability, the NRC is prioritizing activities associated with development of risk-informed and performance-based licensing approaches and early resolution of policy issues, so designers have these insights while developing their design and license application. The NRC is making significant progress in these areas with the issuance of DG-1353, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology To Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors" (Ref. 25), and the NRC staff is actively working to resolve policy issues associated with emergency preparedness, physical security, functional containment, siting, and insurance. These activities are discussed in more detail in the NRC's report entitled "Increasing the Use of Risk-Informed and Performance-Based Evaluation Techniques and Regulatory Guidance in Licensing Commercial Advanced Nuclear Reactors," which is required by Section 103(c) of NEIMA. In addition, the NRC encourages preapplication interactions with advanced reactor developers to provide stability and predictability in the licensing process through early identification and resolution of technical and policy issues that would impact licensing. Another aspect of predictability is the establishment of review milestones and providing applicants with an opportunity to discuss them. This practice has been established through the development of licensing project plans.

INCORPORATION OF CONSENSUS-BASED CODES AND STANDARDS INTO THE REGULATORY FRAMEWORK (Sec. 103(b)(4)(B)(iv))

The NRC encourages the development and use of consensus codes and standards as part of its regulatory programs and can incorporate the codes and standards into regulations and guidance documents.

The NRC staff is enhancing the NRC's technical readiness for possible advanced reactor designs by applying its established process for incorporating codes and standards into its regulatory framework. NRC Management Directive (MD) 6.5, "NRC Participation in the Development and Use of Consensus Standards," dated October 28, 2016 (Ref. 26), describes this process, which consists of three primary steps: (1) identifying and prioritizing the need for new and revised technical standards, (2) participating in codes and standards development, and (3) endorsing codes and standards. The NRC works with standards development organizations (SDOs), advanced reactor developers, DOE, and other stakeholders to identify new codes needed for advanced reactor development and facilitate their development. Some specific activities related to the development and endorsement of consensus codes and standards are discussed below.

COLLABORATION WITH STANDARDS-SETTING ORGANIZATIONS (Sec. 103(b)(4)(B)(iii))

The NRC's Annual Standards Forum

The purpose of the NRC's annual Standards Forum is to help identify needed standards within the nuclear industry that SDOs are not currently addressing and to collaboratively accelerate their development. On September 11, 2018, the NRC staff held the third annual NRC Standards Forum, chaired by the NRC's Standards Executive. Approximately 70 attendees participated, representing SDOs such as the American Society of Mechanical Engineers (ASME), the American Nuclear Society (ANS), the American Society for Testing and Materials, and the Institute of Electrical and Electronics Engineers; representatives from industry; and the Electric Power Research Institute (EPRI). Several representatives from DOE and DOE national laboratories also participated. The Standards Forum allowed the NRC to solicit input from industry stakeholders and encourage interaction to help facilitate development and reduce duplicative work. Further, DOE offered to assist stakeholders in the nuclear power industry to find information to support standards development, particularly for non-LWRs, by accessing DOE's Gateway for Accelerated Innovation in Nuclear program.

As a follow-up to the 2017 Standards Forum, ANS and the NRC held a joint workshop on May 2, 2018, for industry stakeholders to develop a strategic vision for advanced reactors standards. The Technical Working Groups (TWGs) for the major advanced reactor types (HTGRs, MSRs, and liquid-metal fast reactors) were represented at the workshop. The TWG representatives presented an overview of the technologies and identified potential needs for future standards. Generally, the TWGs recognized the benefit of standards, particularly endorsed standards. However, the lack of an existing standard was not expected to delay the development of advanced reactors, in that if standards were not available, designers could develop guidance. The TWGs emphasized that the NRC should place a high priority on the endorsement of ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Division 5, and the joint ASME/ANS non-LWR probabilistic risk assessment (PRA) standard.

ASME B&PV Code, Section III, Division 5, for High-Temperature Reactors

The NRC is actively participating in subgroups and working groups associated with the development of ASME B&PV Code, Section III, Division 5. The NRC staff is also participating in the task group on ASME/NRC Liaison for Division 5, which seeks NRC, DOE, and industry stakeholder input in identifying gaps in ASME B&PV Code, Section III, Division 5 that need to be resolved prior to considering endorsement in 10 CFR 50.55a, "Codes and Standards." ASME sent a letter to the NRC staff confirming that advanced reactor developers support NRC endorsement of the 2017 edition of ASME B&PV Code, Section III, Division 5. Therefore, the NRC staff is initiating the endorsement process for ASME B&PV Code, Section III, Division 5. The NRC staff discussed its plans for endorsement of ASME B&PV Code, Section III, Division 5 during the NRC's annual Standards Forum on September 11, 2018, and during the periodic advanced reactor stakeholder meeting held on September 13, 2018, and June 27, 2019.

ASME/ANS Non-LWR PRA Standard

The ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM) issued ASME/ANS RA-S-1.4-2013, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants" (Ref. 27), for trial use in 2013. Source material from the existing ASME/ANS Level 1, full power, LWR PRA standard, as revised in 2013, as well as draft LWR PRA standards for low-power and shutdown PRA, Level 2 PRA, and Level 3 PRA, have been used, where appropriate, in developing the technical requirements for this standard. ASME and ANS are developing a new edition of the Level 1, full power, LWR PRA standard, which they expect to issue in 2020.

On February 7, 2019, the NRC Standards Executive issued a letter to ASME Board Chair and ANS Standards Board Chair (Ref. 28) communicating the priority of various PRA standard development activities and identifying the completion of the non-LWR PRA standard as a high priority.

<u>ANS Safety Standards</u>

The NRC provides representation on several ANS standards working groups and consensus committees, including the following:

- Research and Advanced Reactor Consensus Committee Risk-Informed, Performance-Based, Principles and Policy Committee;

- ANS 53.1, "Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants";

- ANS 54.1, "Nuclear Safety Criteria and Design Process for Liquid-Sodium-Cooled Nuclear Power Plants";

- ANS 20.2, "Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten-Salt Reactor Nuclear Power Plants";

- ANS 30.1, "Integrating Risk and Performance Objectives into New Reactor Nuclear Safety Designs" (Proposed); and

- ANS 30.2, "Categorization and Classification of Structures, Systems, and Components for New Nuclear Power Plants" (Proposed).

The NRC will continue its membership and participation on ANS committees and standards development working groups to support standards for advanced reactor technologies, where appropriate.

STRATEGIES FOR FUEL QUALIFICATION (Sec. 103(b)(4)(A)(ii))

Across the various advanced reactor designs, several fuel types are being considered, including fuels based on tristructural isotropic (TRISO) particles, metallic uranium alloys, and liquid salt fuels. TRISO fuel consists of many small uranium kernels coated with layers of carbon and silicon carbide that is used in HTGRs and one type of a fluoride-salt-cooled reactor. Metallic fuel is often a uranium-zirconium alloy used in sodium-cooled fast reactors and other fast reactor designs. Liquid salt fueled reactors have the nuclear fuel dissolved in the molten salt coolant. The NRC is interacting with DOE and national laboratories on the qualification of each of the fuel forms being considered for advanced reactor designs, as well as the qualification of accident tolerant fuel, which is addressed in Section 107 of NEIMA. The NRC is coordinating activities related to fuel qualification with DOE, individual reactor developers, and other stakeholders.

In May 2019, EPRI submitted topical report EPRI-AR-1 (NP), “Topical Report on Uranium Oxycarbide (UCO) Tristructural Isotropic (TRISO) Coated Particle Fuel Performance” (Ref. 29). TRISO coated particle fuel is foundational for many high-temperature reactor (HTR) designs, including HTGRs and FHRs. The report was co-funded by EPRI and DOE, with the involvement of HTR developers. DOE initiated the Advanced Gas Reactor (AGR) fuel development and qualification program in 2002 to establish the capability in the United States to fabricate high-quality UCO TRISO fuel and to demonstrate its performance. This EPRI report consolidates the technical basis for the functional performance of UCO TRISO-coated particles, based on the AGR test program, to support their use by a variety of HTR developers in their designs. The NRC is currently reviewing this topical report.

The NRC also anticipates that DOE will submit a topical report describing the metal fuels legacy data quality assurance program in fiscal year 2019. As part of its review of the topical report, the NRC plans to perform an audit of the implementation process. The NRC is also working with stakeholders, including DOE, to ensure that possible regulatory issues with the planned use of high-assay, low-enriched uranium in some advanced reactor designs are identified and resolved, including any needed licensing of fuel cycle facilities and transportation packages.

In addition, through DOE funding, General Atomics is continuing development of new types of fuel for advanced reactors. The funded projects will advance development and licensing of a new reactor fuel that features silicon carbide (SiC) composite fuel cladding containing uranium carbide (UC) fuel pellets. The first project will combine advanced computer modeling and simulation with experimental validation to establish techniques that may reduce the time and expense required to qualify new fuels, and the second project will support the preapplication license review of SiC-UC fuel by the NRC. General Atomics plans to submit a topical report requesting NRC review and approval of its proposed fuel qualification methodology.

The NRC, with the support of Oak Ridge National Laboratory (ORNL), is developing criteria for the qualification of fuel for liquid-fueled molten salt reactors. As part of this effort, ORNL prepared a report ORNL/LTR-2018/1045, “Molten Salt Reactor Fuel Qualification Considerations and Challenges,” published in November 2018 (Ref. 30).

The NRC will continue to work on these generically applicable fuel qualification activities and will engage with advanced reactor developers on specific issues related to qualification of their fuel designs. The NRC anticipates that several advanced reactor developers will support the submittal of topical reports in the near term for NRC review and approval of their fuel qualification plans. The NRC encourages these interactions to provide early engagement and feedback on key technical issues in support of staged licensing approaches.

The near-term efforts, such as the review of the EPRI topical report, are expected to be completed by January 2021. Efforts associated with qualification of other fuel designs are closely linked to advanced reactor efforts and licensing project plans. As these proposals are presented to the NRC, the NRC staff will develop associated NRC review plans to establish expectations in terms of outcomes, resources, and schedules to reach agreement on the desired outcomes of defined interactions.

EXTENT TO WHICH COMMISSION ACTION OR MODIFICATION OF POLICY IS NEEDED TO IMPLEMENT THIS REPORT (Sec. 103(b)(4)(E))

The NRC has not identified any Commission action or modification of policy that is needed to establish stages in the licensing process for commercial advanced nuclear reactors. The existing NRC regulations, as discussed in the Roadmap, provide multiple regulatory processes to support design development activities and appropriate interactions between the NRC staff and stakeholders at various stages of the reactor design process.

LEGAL, REGULATORY, AND POLICY ISSUES WITH REGARD TO LICENSING (Sec. 103(b)(4)(A)(iii))

The NRC has been identifying and resolving policy issues related to advanced reactors since the 1980s. The NRC has focused on evaluating those issues that impact regulatory reviews, siting, permitting, and/or licensing of advanced reactors; this effort supports the subsequent identification and resolution of policy issues. Early identification and resolution of policy issues, through preapplication engagement and staged licensing approaches, help to achieve the objective of enhanced technical and regulatory readiness and communications.

Although, as discussed in the previous section of this report, the NRC has not identified any policy actions that are needed for the specific purpose of establishing stages in the licensing process for commercial advanced nuclear reactors, the NRC staff is considering several policy issues regarding other matters related to the licensing of SMRs and non-LWRs. These policy issues include appropriate source term, offsite emergency planning, insurance and liability, security and safeguards requirements, and functional containment performance. These policy issues have been discussed routinely in public stakeholder meetings. These discussions will continue for the NRC to obtain stakeholder input on the identification and resolution of policy issues and to help prioritize these issues. The NRC continues to provide the status of these policy issues in monthly and semiannual reports to Congress.

A more detailed discussion of specific policy issues related to development and implementation of risk-informed and performance-based evaluation techniques and guidance is provided in the NRC's report entitled "Increasing the Use of Risk-Informed and Performance-Based Evaluation Techniques and Regulatory Guidance in Licensing Commercial Advanced Nuclear Reactors," as required by Section 103(c)(4)(A) of NEIMA.

CONCLUSION

The Advanced Reactor Vision and Strategy Document has guided the development of IAPs that support achievement of the agency's overarching strategic goals and objectives, including assuring readiness to effectively and efficiently review and regulate advanced reactors. The Advanced Reactor Vision and Strategy Document, related IAPs, and subsequent status papers describe the objectives, strategies, and contributing activities necessary to achieve advanced reactor mission readiness. Several key activities for ensuring NRC processes that support a staged licensing approach, including issuance of the Roadmap, were expedited and among the first items completed under the IAPs for the agency's advanced reactor program. As previously discussed, while much of the efforts to implement strategies to establish stages in the licensing process for advanced reactors has been focused on their application to non-LWR designs, the efforts are equally applicable to LWR designs.

ACRONYMS

ACRS	Advisory Committee on Reactor Safeguards
AGR	Advanced Gas Reactor
ANS	American Nuclear Society
ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel
CANDU	Canadian Deuterium Uranium
DC	design certification
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
FHR	fluoride-salt-cooled high-temperature reactor
GDC	general design criterion
HTGR	high-temperature gas-cooled reactor
HTR	high-temperature reactor
IAP	implementation action plan
LWR	light-water reactor
MD	Management Directive
MHTGR	Modular High-Temperature Gas-Cooled Reactor
MSR	molten salt reactor
NEI	Nuclear Energy Institute
NGNP	Next Generation Nuclear Plant
NIA	Nuclear Innovation Alliance
non-LWR	non-light-water reactor
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDC	principal design criterion
PIUS	Process Inherent Ultimate Safety
PRA	probabilistic risk assessment
PRISM	Power Reactor Innovative Small Module
R&D	research and development
RG	Regulatory Guide
SDA	standard design approval
SDO	standards development organization
SFR	sodium-cooled fast reactor
SiC	silicon carbide
SMR	small modular reactor
SRM	Staff Requirements Memorandum
SSC	structure, system, or component
TRISO	tristructural isotropic
TWG	technical working group
UC	uranium carbide

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