U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

# NON-LIGHT WATER REACTOR IMPLEMENTATION ACTION PLAN—PROGRESS SUMMARY AND FUTURE PLANS

Enclosure 1

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## 1.0 Introduction

To prepare to review and regulate non-light water reactors (non-LWRs), the U.S. Nuclear Regulatory Commission (NRC) developed a vision and strategy to ensure NRC readiness to efficiently and effectively conduct its mission for these technologies, including fuel cycles and waste forms. The document, "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," issued December 2016[1] (non-LWR Vision and Strategy Document), is the overarching document that describes the objectives, strategies, and contributing activities necessary to achieve non-LWR mission readiness.

To achieve the goals and objectives stated in its non-LWR Vision and Strategy Document, the NRC has developed implementation action plans (IAPs). The IAPs identify the specific activities the NRC will conduct in the near-term (within 5 years), mid-term (5–10 years), and long-term (beyond 10 years). The NRC released its draft IAPs to obtain stakeholder feedback during a series of public meetings held between October 2016 and March 2017. The staff also briefed the Advisory Committee on Reactor Safeguards (ACRS) on March 8 and 9, 2017. The staff considered the ACRS comments and stakeholder feedback in the final Near-Term[2], Mid-Term and Long-Term[3] IAPs, issued on July 12, 2017.

The near-term IAP 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 (not specific to a particular non-LWR design or category) policy issues 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.

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1 See "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," dated December 21, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16356A670).

2 See "NRC Non-Light Water Reactor Near-Term Implementation Action Plans," dated July 12, 2017 (ADAMS Accession No. ML17165A069).

3 See "NRC Non-Light Water Reactor Mid-Term and Long-Term Implementation Action Plans," dated July 12, 2017 (ADAMS Accession No. ML17164A173).

Based on input received from stakeholders on the draft near-term IAP and ACRS recommendations, the NRC prioritized its execution of Strategies 3 and 5 in the near term; however, some activities are ongoing in support of all six strategies commensurate with available resources. The sections below provide additional information on the status and next steps for each of the strategies.

The IAPs support the goal of assuring NRC readiness to effectively, efficiently, and predictably review non-LWR applications by 2025. The NRC selected this timeframe to align with the U.S. Department of Energy's (DOE's) non-LWR vision and strategy, which sets forth a goal of having at least two non-LWR concepts ready for construction in the early 2030s. The NRC recognizes that non-LWR developers may wish to begin preapplication activities or submit applications for review in the near-term, in advance of DOE's deployment goal. In those cases, the NRC will work with developers on design-specific regulatory engagement plans, as discussed in Strategy 3, and the NRC may prioritize or accelerate specific contributing activities in this IAP, as needed. The NRC will also continue to seek information from prospective applicants to ensure that technology-inclusive readiness activities will be supportive of the plans of near-term applicants.

The NRC assumed that the strategies and contributing activities described in the IAPs would not be constrained by budget or by other agency mission priorities. The staff made this assumption to facilitate the exercise of describing the activities and sequencing needed to accomplish non-LWR readiness and to estimate the resources that will be needed to complete those activities, without fiscal prejudice. By doing so, the NRC developed a work plan that could be executed as resources become available. This approach provides the NRC with a basis for future budget formulation and informs discussions of NRC resource needs relative to other Commission, Executive Branch, and Congressional priorities.

This enclosure provides the status of each of the readiness strategies, with an emphasis on accomplishments achieved through the end of December 2017. This enclosure also describes next steps and planned activities for fiscal year (FY) 2018. The activities the NRC has planned in FY 2018 have been informed by input received from stakeholders and are reflective of available resources and staff members who have the necessary skills.

## 2.0 Strategy 1: Acquire/Develop Sufficient Knowledge, Technical Skills, and Capacity to Perform Non- Light Water Reactors Regulatory Reviews

### 2.1 Overview

This strategy supports the non-LWR Vision and Strategy objective of enhancing non-LWR technical readiness:

> …the staff has the requisite knowledge, expertise, tools, and processes needed to efficiently and effectively evaluate a non-LWR application, and to reach an independent safety, security, or environmental finding.

To support accomplishment of this objective, the non-LWR Vision and Strategy Document described readiness for "people" (the staff) as follows:

> For non-LWRs, the staff must be familiar with a range of potential technologies, must have adequate training support in place, must have a non-LWR knowledge base available, and must have familiarity with system and integrated plant operations. The staff must also be knowledgeable of any unique environmental or security challenges posed by a particular non-LWR technology. While many aspects of non-LWR designs may be technology-inclusive (that is, independent of the particular non-LWR technology being reviewed), subject matter expertise for technology-specific aspects of the designs is also required. The NRC must have the right number of people with the right skills at the right time in order for the staff to conduct an effective and efficient review.

The approach taken for this strategy is based on the principle of designing and maintaining the workforce consistent with the work to be accomplished, in the timeframe needed to support licensing reviews.

The near-term IAP for this strategy focuses on leveraging existing NRC tools to identify work requirements, determine critical skills and staff capacity requirements, assess the current staff's non-LWR technical readiness, and close the technical readiness gap by a variety of methods. The mid-term and long-term IAPs for this strategy address items such as long-range training and staff development for non-LWRs, mentoring programs, and attrition planning. Certain foundational activities, such as organizational assessments, knowledge capture, knowledge management (KM), workforce competency modeling, and strategic workforce planning are continuously conducted in the near-, mid-, and long-term. The Office of the Chief Human Capital Officer (OCHCO) is an integral partner in conducting these foundational activities. As part of the NRC's knowledge capture and management efforts, the staff will also identify historical reference materials that can be made publicly available or more easily accessible to the public. As part of this effort, the staff will also work with DOE, the national laboratories, and other entities to identify additional non-LWR reference materials that should be captured.

The near-term contributing activities and support tasks associated with this strategy throughout the IAPs include both technology-inclusive and technology-specific actions. The staff should be prepared and able to complete the technology-inclusive activities without specialized preparation or training. Technology-specific tasks and the associated critical skills are identified and detailed with the assistance of subject-matter experts (SMEs). These SMEs will be identified and sourced from a variety of organizations, as needed.

Sources of available non-LWR expertise include DOE, as well as its national laboratories; commercial engineering and regulatory support firms; international regulatory bodies and their research partners; intergovernmental organizations, such as the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development, and the Generation IV International Forum; standards development organizations (SDOs), such as the American National Standards Institute (ANSI) and the American Society of Mechanical Engineers (ASME); and the non-LWR industry itself. Strategy 1 activities will be informed by ongoing DOE and industry technology development activities. The NRC will also monitor the plans of prospective applicants to ensure that staff readiness in technology-specific areas is prioritized appropriately.

The near-term IAP identified the following two contributing activities in support of Strategy 1:

> Contributing Activity No. 1.1: Identify Non-LWR Task and Technical Skill Requirements (Work Design Activities)

Contributing Activity No. 1.2: Determine and Establish the Necessary Workforce Skills and Capacities (Workforce Design & Establishment).

## 2.2 Progress Summary

The staff has focused primarily on three activities in support of Strategy 1 in FY 2017: (1) competency modeling, (2) training, and (3) initial efforts in the area of KM.

### 2.2.1 Competency Modeling

Competency modelling for advanced reactor project managers and technical reviewers is part of a pilot project led by OCHCO. A competency model describes what people need to know and be able to do in order to do their job and serves as a tool to identify and help close any skill gaps. The first step in the modeling process is the Rapid Job Task Analysis (JTA). The JTA sessions identify the current job tasks and the required behaviors that are necessary to excel in these positions. OCHCO facilitated JTA sessions on June 14, 2017, and June 28, 2017, with experienced project managers and technical review staff from the Office of New Reactors (NRO) and the Office of Nuclear Reactor Regulation (NRR). Subsequently, OCHCO completed the development of the competency model for advanced reactor project managers and advanced reactor technical reviewers and loaded these competency models into the Self-Directed Learning Engine system. In November 2017 NRO asked project managers and technical reviewers to use the system to begin assessing their skills against the model.

Next steps: NRO project managers and technical staff will complete the skills assessment.. Once the self-assessments have been completed, the supervisors will also be able to complete an independent assessment of their employees' skills. Based on the assessment results, any skill gaps can be determined, and the system will help the employee identify development activities and create an Individual Development Plan to close those gaps. OCHCO also plans to develop more specific technical reviewer competency models to focus on specific technical review areas, such as reactor systems and containment systems.

### 2.2.2 Training

The NRC contracted with the Oak Ridge National Laboratory (ORNL) to develop a 12-module training course on molten-salt reactors (MSRs). The provision of this training to the staff was prioritized to address the lack of familiarity with this technology. The course provided background on various MSR concepts presently under development, including a history of earlier MSR projects, descriptions of conceptual designs, and expected technical and regulatory challenges. About 90 NRC staff from NRO, NRR, the Office of Nuclear Regulatory Research (RES), the Office of Nuclear Material Safety and Safeguards, Office of Nuclear Security and Incident Response, and the Office of the General Counsel, along with some DOE staff, enrolled in the training. ORNL delivered the training in three separate 2-day sessions in May, August, and November 2017. ORNL also video recorded the first training session and will make it available to the staff on the NRC intranet.

Several staff from RES received training in the use of DOE's MOOSE and BISON codes. Both of these codes are being developed by the DOE Nuclear Engineering Advanced Modeling and Simulation (NEAMS) project, and can be used to simulate thermo-mechanical behavior of reactor fuel and components. The training was a first step in establishing interoperability of DOE and NRC codes for non-LWR analysis.

Next Steps: The NRC will make the MSR training videos available to the NRC staff. The staff also plans to offer existing training to the staff on sodium-cooled fast reactors (SFRs) and high-temperature gas-cooled reactors (HTGRs). As additional resources become available, the staff will assess training needs and develop additional training courses, as appropriate.

2.2.3 Knowledge Management

Significant information is available on technical, policy, and regulatory issues associated with licensing non-LWR designs. The goal of this activity is to consolidate existing documents and training materials currently on multiple KM sites onto one centralized KM site that is accessible and easily searchable.

Next Steps: The NRC plans to leverage existing NRC KM resources and data repositories to capture available non-LWR information in a manner that can be easily accessed and maintained. The NRC will also coordinate with DOE to leverage access to the non-LWR material on the DOE Gateway for Accelerated Innovation in Nuclear (GAIN) Web site.

## 3.0 Strategy 2: Acquire/Develop Sufficient Computer Codes and Tools to Perform Non- Light Water Reactor Regulatory Reviews

3.1 Overview

This strategy supports the non-LWR Vision and Strategy Document's objective of enhancing non-LWR technical readiness and optimizing regulatory readiness. In support of this objective, the staff must have adequate computer models and analytical tools to conduct its review of non-LWR designs.

As part of the staff's review and licensing of non-LWR designs, the staff will perform confirmatory analysis of design-basis events, beyond design-basis events, and of safety significant structures, systems, and components (SSCs). This provides the staff with a basis to examine the applicant's analysis and to confirm the margin of safety for a given design and its operating condition. To perform these calculations, the staff will need to modify its existing codes and leverage the use of codes developed by other organizations, such as DOE. Currently, the staff has analytical codes that are applicable to current operating and new LWRs, and some have limited non-LWR capabilities. The initial tasks for this strategy will include evaluating existing analytical capabilities, identifying gaps, and then selecting the analytical codes for use by the staff. This is especially true for designs that have the least regulatory experience and that have been the subject of only limited code development efforts.

The best-understood non-LWR technology is the HTGR, for which there has been operating experience in the United States, United Kingdom, Germany, Japan, Russia, and China. Liquid metal fast reactors (LMFRs), specifically SFRs, have been constructed and operated in the United States, Russia, China, United Kingdom, Japan, France, and Germany. Of note is France's Rapsodie SFR, which had a particularly long operating period from 1967 to 1983. MSR designs have far less regulatory review history. ORNL designed and operated an 8-megawatt thermal molten-salt experimental reactor (Molten-Salt Reactor Experiment) from 1965 to 1969.

The approach taken for this strategy is to: (1) identify the computer codes and supporting information and data that would be needed to support both the design of a non-LWR and the

staff's review of that design, (2) evaluate the existing computer codes and supporting information and identify gaps in both analytical capabilities and supporting information and data, and (3) interact with both domestic and international organizations working on non-LWR technologies to identify opportunities to collaborate and cooperate in closing the gaps, while being mindful of the importance of avoiding conflicts of interest. The staff's goal is to leverage, to the extent practicable, collaboration and cooperation with the domestic and international community interested in non-LWRs with the goal of establishing a set of tools and data that are commonly understood and accepted. That community may be composed of the NRC, DOE, developers, utilities, and international regulatory partners. Having a common understanding of the tools and data, rather than having to develop that understanding during each technical review, should significantly improve the efficiency of the review process. The NRC will also participate in the code development process to the degree that resources allow. It is anticipated that the NRC will use the codes to perform confirmatory, sensitivity, and uncertainty analyses to help investigate margins in the design. In some technical areas, an applicant may be required to submit the code documentation for the NRC's review and approval, such as an evaluation model used for design-basis analyses. It would be the applicant's responsibility to show that the quality assurance program used in the code development meets the NRC's requirements outlined in Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." Code development, verification, and validation, collectively known as assessment, can be extremely resource and time intensive. Therefore, it might not be practicable for a single organization to undertake all of the required efforts, particularly in light of current budget realities and the deployment timelines that have been suggested by DOE and the industry. Thus, collaboration and cooperation are essential to the success of the strategy.

The staff has a number of ongoing interactions and collaborative efforts with DOE, the domestic research community, and the international community related to computer codes and analytical tools. The approach will build on these existing interactions, with the goal of developing new cooperative funded activities, as appropriate.

For the purpose of developing the plans for this strategy, the staff has considered the designs of interest in the near term to be HTGRs, SFRs, and MSRs, where the fuel may or may not be dissolved in the coolant. This choice is based on the NRC's experience and is not intended to show preference to the potential non-LWR designs currently being explored by the industry and DOE. The NRC will review this design set frequently during execution of the near-term IAP and will use information on the plans of prospective applicants to prioritize activities and make effective use of the NRC's resources.

The near-term activities that support this strategy involve stakeholder interactions to better understand and assess existing computer codes, information, and data, as well as the gaps between the current state and what is needed. From those assessments, the staff will further engage the technical community to identify mutual interests and the potential for collaborative and cooperatively funded activities to close the identified gaps.

Based on a preliminary assessment of the gaps, the staff developed a set of contributing activities. It will address the following functional areas in the near term: reactor kinetics and criticality, fuel performance, thermal-fluid phenomena, severe accident phenomena, offsite consequence analysis, materials and component integrity, and probabilistic risk assessment (PRA).

## 3.2 Progress Summary

Lack of funding caused a delay in the efforts directed toward computer codes and tools until the latter half of FY 2017, and, as a result, most work remains in progress and will continue into FY 2018.

During FY 2017, the staff began identifying and evaluating computer codes and tools. It directed initial efforts toward familiarization with non-LWR designs and the principal variants being proposed by preapplicants for regulatory review. The staff attended DOE- and NRC-sponsored workshops, technology working groups, preapplicant "drop-in" meetings, and focused training to better understand the reactor systems under development.

The staff prepared a report containing a detailed summary of all FY 2017 efforts on Strategy 2 in the following near-term focus areas: reactor kinetics and criticality, fuel performance, thermal-fluid phenomena, severe accident phenomena, offsite consequence analysis, materials and component integrity, and PRA.[4] This report provides the status of efforts in these areas and discusses FY 2017 accomplishments and planned activities for FY 2018.

The following accomplishments are examples of the significant work completed or nearing completion at the end of FY 2017:

- The staff completed an initial screening of analysis codes for design-basis and beyond design-basis event simulation, and identified a suite of tools for further examination and consideration. The code suite comprises codes developed by both the NRC and DOE. Future efforts will evaluate codes in the code suite against analysis requirements.

- The staff conducted a Phenomena Identification and Ranking Table (PIRT) exercise for MSRs. The PIRT focused attention on fuel salt MSRs because of their novel and unique feature of fuel being part of the coolant. The PIRT is considered preliminary because design specifics are not available, but it is useful in that several phenomena requiring simulation could be identified based on existing information.

- The staff completed a report on PRA. This PRA report summarizes previous work and issues for non-LWRs.

In addition, the staff made significant progress on many other key activities in FY 2017. The following activities are planned for completion in FY 2018:

- The NRC awarded a contract to examine materials related to non-LWR systems. Of main interest are the elevated temperatures at which most non-LWRs propose to operate. The study will also consider corrosion, especially for MSRs. (Materials issues are also being addressed through participation on ASME standards committees, which is a Strategy 4 activity.)

- The NRC awarded a contract to summarize available domestic and international operational experience for non-LWR reactors and computational capabilities in the analyses of non-LWR materials degradation and component integrity issues.

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[4] See staff report, "Strategy 2 Near-Term Implementation Action Plan Progress Report for Fiscal Year 2017," dated November 24,2017 (ADAMS Accession No. ML17319A550).

- The NRC awarded contracts to perform code assessment important to the analysis of pebble bed gas-cooled reactors. The assessment is intended to inform the staff on the capabilities of DOE's PRONGHORN code for gas-cooled reactor analysis.

- The NRC and DOE began a code development activity to couple the NRC's TRACE code with codes developed under the DOE "NEAMS" project. The initial coupling exercise was successful, and validation of the newly developed software is in progress.

- A review of the severe accident modelling and simulation needs for the MELCOR code for non-LWRs was initiated. The objective for FY 2018 is to identify models necessary for SFRs and MSRs.

- Work was initiated to add finitie element modeling capabilities to the FAST fuel performance code. This will enable the NRC's fuel code to simulate steady-state and transient fuel behavior in non-circular geometries including fuel in the form of plates and spheres.

Efforts for FY 2018 will include refinement of the analysis code suite and definition of code requirements for each of the three major advanced technologies.

Next Steps: The staff document, "Strategy 2 Near-Term Implementation Action Plan Progress Report for Fiscal Year 2017," discusses next steps.

## 4.0 Strategy 3: Develop Guidance for a Flexible Non-Light Water Reactor Regulatory Review Process within the Bounds of Existing Regulations, Including the Use of Conceptual Design Reviews and Staged-Review Processes

### 4.1 Overview

This strategy supports the non-LWR Vision and Strategy objective of optimizing non-LWR regulatory readiness:

> Regulatory review processes are optimized when the resources of the NRC and potential applicants are effectively and efficiently used in a way that meets NRC requirements in a manner commensurate with the risks posed by the technology, that maximizes regulatory certainty, and that considers the business needs of potential non-LWR applicants. Additional options for long-range changes for non-LWR regulatory reviews and oversight that would require rulemaking will also be considered. Regulatory readiness includes the clear identification of NRC requirements and the effective and timely communication of those requirements to potential applicants in a manner that can be understood by stakeholders with a range of regulatory maturity.

One of the objectives of Strategy 3 is to 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. This flexibility will accommodate potential applicants having a range of financial, technical, and regulatory maturity and application readiness.

Interactions between non-LWR designers and the NRC are expected to range from designs in the preconceptual design stage to those in or near the final design stage. In addition, plans for

the overall deployment of non-LWR designs might include multiple projects involving critical decisions for related research and test reactors (RTRs), first-of-a-kind large-scale plants, and commercial plants. The NRC's review and licensing processes are flexible and allow interactions related to this wide variation in design development. Based on interactions with stakeholders, the NRC determined that guidance would be beneficial to assist non-LWR developers in planning regulatory interactions.

To address this need, the NRC developed guidance for its flexible regulatory review processes within the bounds of existing regulations, including the use of conceptual design reviews and staged-review processes in the document, "A Regulatory Review Roadmap for Non-Light Water Reactors."[5] The "roadmap" is also intended to help designers prepare technology- or design-specific regulatory engagement plans. Regulatory engagement plans define desired outcomes from various interactions between the designer and the NRC, considering factors such as the resources available to the designer and the NRC and the coordination of regulatory issues with other aspects of the overall program for developing and deploying non-LWR designs. Regulatory engagement plans also define the timing and scope of regulatory interactions in order to align with stakeholders activities related to plant design, research and development, finance, public policy, and the fuel cycle.

The near-term activities described in this strategy can be used to support longer term efforts to develop, as needed, a new non-LWR regulatory framework that is risk-informed and performance-based and that features staff review efforts commensurate with the demonstrated safety performance of non-LWR technologies.

Strategy 3 also includes the following activities:

(1) Establish criteria, as necessary, to reach a safety, security, or environmental finding for non-LWR technologies.

(2) Determine appropriate licensing bases and accident sets for non-LWR technologies.

(3) Identify and resolve gaps in the current regulatory framework associated with non-LWR reactors and the associated fuel cycle.

(4) Develop a regulatory review "roadmap" reflecting the design development lifecycle and appropriate interactions, including potential RTR interactions.

(5) Update prototype reactor guidance.

(6) Engage on technology- or design-specific licensing project plans and develop regulatory approaches commensurate with the risks posed by the technology.

(7) Support longer-term efforts to develop, as needed, a new non-LWR regulatory framework that is risk-informed and performance based and that features staff review efforts commensurate with the demonstrated safety performance of the non-LWR nuclear power plant design being considered.

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[5] See "A Regulatory Review Roadmap for Non-Light Water Reactors," issued December 26, 2017 (ADAMS Accession No. ML17312B567).

Several of these activities (e.g., decision criteria, licensing bases, and gap analyses) collectively establish a regulatory framework for a specific non-LWR technology and will be closely coordinated.

## 4.2 Progress Summary

### 4.2.1 Staged Licensing Process

As mentioned above, the NRC staff issued the "Regulatory Review Roadmap for Non-Light Water Reactors" as part of developing a flexible review process for advanced reactors. It released the draft roadmap in October 2016 to support ongoing public discussions on possible improvements to regulatory processes; in particular, interactions and decisionmaking during the various stages of the design process for non-LWR technologies. On April 24, 2017, the Nuclear Energy Institute (NEI) submitted a white paper prepared by the Nuclear Innovation Alliance (NIA) on standard design approval (SDA) to define "major portions" of a design. This topic was discussed during several public meetings. The NRC provided feedback on the NIA SDA paper on June 16, 2017, and discussed its input during a public meeting held on June 22, 2017.

The NRC revised the roadmap to reflect stakeholder feedback, to incorporate guidance on prototype testing, and to reference the NIA SDA paper. The staff released the revised draft in October 2017 and discussed it with stakeholders on November 2, 2017. The NRC then issued the final regulatory review roadmap in December 2017.

Next Steps: None; this action is complete.

### 4.2.2 Non-Light Water Reactor Design Criteria

Developing design criteria (DC) for non-LWRs is an important first step in providing stakeholders with insights on how the NRC staff views the unique characteristics of non-LWR technology. The NRC, in collaboration with DOE, has been working on the initiative to develop guidance for principal DC (PDC) for non-LWRs since 2013. The purpose of the initiative is to assess the general design criteria (GDC) to determine whether they apply to non-LWR designs and, if not, to propose DC that address non-LWR design features while recognizing that the underlying safety objective of each applicable GDC still applies.

DOE issued the report titled, "Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors,"[6] for NRC consideration in December 2014. In this report, DOE proposed advanced reactor design criteria (ARDC) that could be used by all current non-LWR technologies. DOE also developed the technology-specific DC to demonstrate how the GDC could be adapted to SFR and modular high-temperature gas-cooled reactor (MHTGR) technologies in which there was some level of maturity and documented design information available. DOE determined that the safety objectives for some of the current GDC did not address design features specific to SFR and MHTGR technologies (e.g., sodium or helium coolant, passive heat removal systems). Additional DC were developed to address the unique features of those technologies.

[6] See "Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors," dated December 8, 2014 (ADAMS Accession Nos. ML14353A246 and ML14353A248).

After reviewing the DOE report and supporting documentation, the NRC developed its own version of the ARDC, SFR-DC, and MHTGR-DC and issued draft regulatory guide DG-1330 "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors,"[7] for public comment on February 3, 2017. DG-1330 provides guidance to reactor designers, applicants, and licensees of non-LWR designs for developing PDC for any non-LWR designs subject to 10 CFR Part 50 and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The non-LWR DC developed by the NRC staff, and included in Appendices A to C of the draft regulatory guide, are intended to provide stakeholders with insight into the staff's views on how the GDC could be interpreted to address non-LWR design features. These are not considered to be final or binding about what may eventually be required from a non-LWR applicant. Since the GDC are considered guidance for non-LWRs, non-LWR applicants would not need to request an exemption from the GDC in 10 CFR Part 50 when proposing PDC for a specific design. They may use the final regulatory guide to develop all or part of the PDC and are free to choose among the ARDC, SFR-DC, or MHTGR-DC to develop each PDC.

The public comment period for DG-1330 ended on April 21, 2017. The NRC received more than 120 public comments. The most significant comments included discussions about reactivity control, electric power, residual heat removal, containment, and emergency core cooling. The staff discussed the comments during public meetings on August 24, September 23, and November 2, 2017.

Next Steps: The staff will release the draft final regulatory guide in support of ACRS subcommittee and full committee meetings that will be held on February 7, 2018, and March 8, 2018, respectively. The NRC expects to issue final guidance in spring 2018 in Regulatory Guide 1.232, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors."

### 4.2.3 Security Design Considerations

The Commission's "Policy Statement on the Regulation of Advanced Reactors,"[8] states that the design of advanced reactors should "include considerations for safety and security requirements together in the design process such that security issues (e.g., newly identified threats of terrorist attacks) can be effectively resolved through facility design and engineered security features, and formulation of mitigation measures, with reduced reliance on human actions." In 2016, the NRC considered including in the ARDC (described in Section 4.2.2) criteria on physical security and cybersecurity. The NRC instead decided to retain the safety focus of the ARDC and to not include criteria for security. However, the NRC decided to separately produce a guidance document that would describe several considerations for advanced reactor designers related to physical security and cybersecurity.

On March 13, 2017, the NRC published a notice[9] and request for a 45-day public comment period in the *Federal Register* on preliminary draft guidance on non-LWR security design

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7 See "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors," dated February 3, 2017 (ADAMS Accession No. ML16301A307).

8 See Volume 73 of the *Federal Register*, page 60612 (73 FR 60612), "Policy Statement on the Regulation of Advanced Reactors," dated October 14, 2008.

9 See 82 FR 13511, "Non-Light Water Reactor Security Design Considerations," dated March 13, 2017.

considerations.[10] This document sets forth a set of "security design considerations" that a designer should consider while developing the facility design. These considerations, if adequately implemented through detailed design, along with the adequate implementation of administrative controls and security programs, are one way to protect a nuclear power reactor against the design-basis threat for radiological sabotage. The comment period closed on April 27, 2017. The NRC received one public comment that recommended the guidance be revised to recognize the unique attributes of advanced reactors, rather than providing an overview of the existing regulatory requirements in 10 CFR Part 73. The comment further suggested that the NRC should instead act on an NEI white paper that proposed new physical security requirements that are more appropriate for advanced reactor technologies.

Next Steps: The NRC evaluated the public comment and determined that this activity should be put on hold. The NRC is instead focusing on whether it should develop consequence-based security requirements for small modular reactors (SMRs) and non-LWRs, as discussed in Section 6.2.3.

### 4.2.4 Prototype Guidance

Under 10 CFR 50.43(e), an applicant for an advanced reactor design needs to demonstrate the performance of safety features through a combination of analysis, testing, and experience. The rule allows the use of a prototype plant to fulfill the testing requirements and states that the NRC may impose additional requirements on siting, safety features, or operational conditions for the prototype plant during the testing period. The provisions in NRC regulations for a prototype plant have not been exercised, and there was no previous regulatory guidance on the use of prototype plants to satisfy testing requirements.

The NRC staff prepared a white paper on the requirements in 10 CFR 50.43(e) for demonstrating the performance of safety features and on the use of a prototype plant to acquire data to support the safety case of subsequent standardized units. The white paper built on the process for determining testing needs provided in SECY-91-074, "Prototype Decisions for Advanced Reactor Designs," dated March 19, 1991.[11]

On June 16, 2017, the NRC issued a preliminary draft document, "Nuclear Power Reactor Testing Needs and Prototype Plants for Advanced Reactor Designs." This document described the relevant regulations governing the testing requirements for advanced reactors, describes the process for determining testing needs to meet the NRC's regulatory requirements, clarifies when a prototype plant might be needed and how it might differ from the proposed standard plant design, and describes licensing strategies and options that include the use of a prototype plant to meet the NRC's testing requirements. This preliminary draft document was a first step in communicating with stakeholders about prototype testing for advanced reactors. The document was discussed at the August 2017 stakeholder public meeting on advanced reactor topics, and at that meeting, stakeholders provided some initial feedback on the document.

The NRC addressed stakeholder feedback on the prototype paper and incorporated the prototype white paper into the regulatory review roadmap (described in Section 4.2.1). The staff

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[10] See "Preliminary Draft Guidance: Non-Light Water Reactor Security Design Considerations," dated March 13, 2017 (ADAMS Accession No. ML16305A328).

[11] See SECY-91-074, "Prototype Decisions for Advanced Reactor Designs," dated March 19, 1991 (ADAMS Accession No. ML003707900).

discussed the changes to the white paper during a public meeting on November 2, 2017, and published it as part of the regulatory review roadmap in December 2017.

Next Steps: None; this action is complete.

4.2.5 Licensing Modernization Project

The NRC is supporting activities related to the Licensing Modernization Project (LMP) being led by Southern Company, coordinated by NEI, and cost shared by DOE. The LMP's objective is to develop technology-inclusive, risk-informed, and performance-based regulatory guidance for licensing non-LWRs for the NRC to review and potentially endorse. The NRC is currently reviewing four LMP white papers on the selection of licensing-basis events (LBEs),[12] PRA,[13] safety classification for SSCs,[14] and defense-in-depth (DID).[15] The NRC continues to discuss the LMP project with industry and other interested stakeholders during a series of public meetings.

The identification and analysis of LBEs is a key aspect of designing and licensing nuclear power plants. In the LMP's LBE white paper, the industry has proposed a technology-inclusive, risk-informed, and performance-based approach to identifying LBEs, which cover a spectrum of events considered in the design and licensing of a nuclear power plant. One key licensing outcome of this approach is expected to be a structured selection of design-basis accidents that are traditionally analyzed in Chapter 15 of the license application. The NRC provided feedback to LMP on the LBE white paper on May 25, 2017.[16]

The LMP's white paper on PRA outlines a proposed approach to develop a PRA for non-LWR designs in support of risk-informed and performance-based applications including an evaluation of design alternatives and incorporation of risk insights into early and continuing development of the design, input to the selection of LBEs, and input to the safety classification of SSCs. The NRC provided feedback to LMP on the PRA white paper on August 18, 2017.[17]

The LMP's white paper on the safety classification of SSCs describes a proposed technology-inclusive, risk-informed, and performance-based approach for the safety classification of SSCs and the derivation of requirements necessary to support SSC

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12 See Draft Report, "Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors—Selection of Licensing Basis Events," issued April 2017 (ADAMS Accession No. ML17104A254).

13 See Draft Report, "Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors—Probabilistic Risk Assessment Approach," issued June 2017 (ADAMS Accession No. ML17158B543).

14 See Draft Report, "Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Safety Classification and Performance Criteria for Structures, Systems, and Components," dated October 11, 2017 (ADAMS Accession No. ML17290A463).

15 See Draft Report, "Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Risk-Informed and Performance-Based Evaluation of Defense-in-Depth Adequacy," dated December 12 (ADAMS Accession No. ML17334B184).

16 See feedback to LMP on LBE white paper, dated May 25, 2017 (ADAMS Accession No. ML17145A531).

17 See feedback to LMP on PRA white paper, dated August 18, 2017 (ADAMS Accession No. ML17233A187).

performance of safety functions in the prevention and mitigation of LBEs. The white paper presents an approach for determining the risk and safety significance of SSCs, discusses the roles of SSC reliability and capability in the prevention and mitigation of accidents, and describes a process for the development of SSC special treatment requirements. The NRC provided feedback to LMP on the SSC white paper on November 2, 2017.[18]

The fourth LMP white paper on DID describes a proposed technology-inclusive, risk-informed, and performance-based approach for defining DID and evaluating the adequacy of DID in the design capabilities and in the selection of programs to ensure DID adequacy. It also proposes how DID will be taken into account in the risk-informed decisions to select LBEs, the safety classification of SSCs, and the selection of SSC performance requirements.

Next Steps: The NRC will manage the topics of selection of LBEs, the use of PRA, the safety classification for SSCs, and DID primarily through the staff's initial interactions with the industry and other stakeholders on the associated white papers submitted by the LMP. The NRC will continue to engage NEI and other stakeholders on these topics to resolve the relevant technical and potential policy issues during periodic stakeholder meetings. The next step will be for the NRC to provide feedback on the DID white paper. After stakeholder interactions are complete on all these white papers, NEI plans to submit a consolidated guidance document and request NRC endorsement. The integrated approach being developed through the interactions with LMP and other stakeholders is also key to the staff's proposed resolution of policy issues, such as containment functional performance, discussed in Section 6.2.5.

### 4.2.6 Additional Guidance Development Activities Planned for Fiscal Year 2018

In addition to the specific activities discussed in Sections 4.2.1–4.2.5 of this enclosure, the near-term IAPs identified two broad regulatory framework development activities in support of Strategy 3. These activities are to: (1) establish criteria, as necessary, to reach a safety, security, or environmental finding for non-LWR technologies and (2) identify and resolve gaps in current regulatory framework associated with non-LWR reactors and the associated fuel cycle.

In FY 2018, the staff plans to initiate work on fuel qualification, non-LWR research reactors or test facilities, and fuel cycle issues related to high-assay, low-enriched uranium (HALEU).

During a meeting on August 28, 2017, representatives of the non-LWR technology working groups and DOE national laboratories made presentations on the status of fuel qualification for HTGRs, fast reactors, and MSRs. Based on these presentations, it is anticipated that one or more topical reports on non-LWR fuel qualification may be submitted in FY 2018. The NRC is preparing to review these reports when submitted. In addition, the NRC is developing draft guidance on fuel qualification criteria for MSRs.

The NRC plans to leverage, as appropriate, any synergies that may exist between the ongoing activities with qualification of accident tolerant fuel for the operating LWR fleet and the NRC's planned activities with qualification of non-LWR fuel for advanced reactor designs, to help improve the effectiveness and efficiency of NRC's reviews.

NEI is preparing a white paper to be submitted in calendar year (CY) 2018 to discuss the guidance needed to support effective and efficient regulatory reviews for RTRs using

[18] See summary of November 2, 2017 meetgins, including feedback to LMP on SSC, dated November 21, 2017 (ADAMS Accession No. ML17319A210).

molten-salt technology. The staff plans to consider this white paper as well as existing NRC guidance (e.g., NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," issued February 1996, and related interim staff guidance) to develop guidance for non-LWR RTRs.

On November 2, 2017, NEI presented[19] some potential regulatory gaps associated with the non-LWR fuel cycle, specifically with regard to proposed reactors that would use HALEU. NEI submitted a draft white paper on this topic on December 6, 2017.[20] The NRC plans to engage with NEI and interested stakeholders on regulatory issues associated with HALEU and proceed with guidance development activities, as needed.

Next Steps: The NRC is expecting industry submittals on fuel qualification for TRISO fuel, fuel qualification of metallic fuel for SFRs, proposed guidance for MSR RTRs, and a final white paper describing the industry's views on potential regulatory gaps for HALEU. The NRC plans to review these submittals with technical support from the DOE national laboratories. The NRC also plans to initiate efforts to establish criteria for MSR fuel qualification, since this type of fuel is very different than that used in operating reactors. In addition, the NRC plans to develop a draft white paper to explore the NRC's readiness to license non-LWR RTRs.

## 5.0 Strategy 4: Facilitate Industry Codes and Standards Needed to Support the Non-Light Water Reactor Life Cycle (Including Fuels and Materials)

### 5.1 Overview

This strategy supports the non-LWR Vision and Strategy Document objective of enhancing non-LWR technical readiness and optimizing regulatory readiness.

The NRC must consider adapting its regulatory framework to continue to ensure that new and innovative non-LWR designs are constructed and operated to protect public health and safety and the environment. In line with current practice, the NRC expects to use industry consensus codes and standards as an integral part of the agency's strategy to improve its readiness to effectively and efficiently review and regulate non-LWR technologies.

The staff intends to enhance the NRC's technical readiness for possible non-LWR designs by applying its established process for incorporating codes and standards into its regulatory framework. The NRC describes this process in Management Directive 6.5, "NRC Participation in the Development and Use of Consensus Standards," and it 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 will work with SDOs, non-LWR designers, DOE, and other stakeholders to identify and facilitate new codes needed for non-LWR development. The NRC maintains its independence during participation with SDOs by reserving the right to apply conditions on codes and standards used in its regulatory process to ensure that they will meet the NRC's requirements to protect public health and safety and the environment. The need to impose conditions may, however, be reduced by attempts to resolve outstanding issues through

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[19] See NEI slides on HALEU dated November 2, 2017 (ADAMS Accession No. ML17310B495).

[20] See Draft NEI white paper "Addressing the Challenges with Establishing the Infrastructure for the front end of the Fuel Cycle for Advanced Reactors," dated December 6, 2017 (ADAMS Accession No. ML17341A604).

meetings with SDOs and other stakeholders and through the NRC's active participation during the codes and standards development process.

Codes and standards that could be applied to a range of non-LWR designs are likely to be identified beginning in the near-term (0–5 years) as candidates for facilitation and development. One example is the need for codes for high-temperature materials for operating conditions well above the temperatures encountered in LWR operating conditions. Technology-specific codes and standards required by individual developers will likely be identified in the midterm (5-10 years) or long term (10 or more years) as the designs mature. If technology-specific codes are identified by designers planning to begin preapplication or application reviews in the near-term, then the NRC will prioritize its efforts accordingly.

## 5.2 Progress Summary

### 5.2.1 The American Society of Mechnical Engineers Section III, Division 5, for High-Temperature Reactors

The ASME Boiler and Pressure Vessel (B&PV) Code provides NRC-accepted rules for the design, construction, testing, certification, and quality assurance of LWRs with systems operating below 800 degrees fahrenheit. However, non-LWR designs may incorporate novel materials or systems operating above 800 degrees fahrenheit.

The ASME B&PV Code, Section III, Division 5, provides rules for the design, construction, testing, certification, and quality assurance of high-temperature reactors. The scope of ASME B&PV Code, Section III, Division 5, rules covers the use of metallic, graphite, and composite materials. The NRC has identified the 2017 Edition of this standard for potential endorsement to improve the efficiency and effectiveness of the agency's review process, provide the non-LWR designers a stable set of rules for reactor development, and facilitate the certification of non-LWR component vendors.

The NRC staff 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 input in identifying gaps in ASME B&PV Code Section III, Division 5, that need to be resolved before the NRC considers endorsing it in 10 CFR 50.55a, "Codes and Standards." ASME is planning to publish an updated edition of the B&PV Code, Section III, Division 5, in 2019.

Currently, ASME is not working on an equivalent of ASME B&PV Code, Section XI, or the ASME Operation and Maintenance Code for high-temperature reactors.

Next Steps: The staff is currently seeking input from non-LWR developers to determine whether the NRC should begin the endorsement process for the 2017 Edition of the ASME B&V Code. The staff discussed this topic with stakeholders during a December 14, 2017, public meeting. During this meeting, the non-LWR developers represented expressed the view that the staff should begin the endorsement process for the 2017 Edition of ASME B&PV Code, Section III, Division 5. ASME is responding to a request from the staff to collect views from the non-LWR technology working groups and more formally request NRC endorsement. The staff will start planning this activity in FY 2018 and expects to begin the endorsement process when additional resources are available.

### 5.2.2 American Nuclear Society Standards

The NRC provides representation on several American Nuclear Society (ANS) standards working groups and consensus committees, shown on the table below with the status of each.

| Standard/Committee | Status |
|---|---|
| Research and Advanced Reactor Consensus Committee | Next meeting scheduled June 2018 |
| Risk-informed, Performance-based, Principles and Policy Committee | Next meeting scheduled June 2018 |
| ANS 53.1, "Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants | Issued 2011<br>Reaffirmed 2016 |
| ANS 54.1, "Nuclear Safety Criteria and Design Process for Liquid-Sodium-Cooled Nuclear Power Plants" | Draft standard submitted to the Research and Advanced Reactor Consensus Committee, Advanced Initiatives Subcommittee. |
| ANS 20.1, "Nuclear Safety Criteria and Design Process for Fluoride Salt-Cooled High-Temperature Reactor Nuclear Power Plants" | Project Initiation Notification System (PINS) form submitted to ANSI on February 26, 2014. Draft standard is in development.<br><br>The NRC's participations in this activity is minimal because of the limited applicability of this standard at this time. However, the NRC will maintain awareness of this activity. |
| ANS 20.2, "Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten-Salt Reactor Nuclear Power Plants" | PINS form submitted to ANSI on July 7, 2016. Working group has held several meetings and conference calls. Draft standard is in development. |
| ANS 30.1, "Integrating Risk and Performance Objectives into New Reactor Nuclear Safety Designs" (Proposed) | Proposed, PINS form submitted to ANSI on July 31, 2016. |
| ANS 30.2, "Categorization and Classification of Structures, Systems, and Components for New Nuclear Power Plants" (Proposed) | Proposed, PINS form submitted to ANSI on July 7, 2016. |

Next Steps: The NRC will continue its membership and participation on ANS committees and standards development working groups to support standards for non-LWR technologies, where appropriate.

### 5.2.3 The U.S. Nuclear Regulatory Commission Standards Forum

The purpose of the Standards Forum is to help identify needed standards within the nuclear industry that are currently not being addressed by SDOs and to collaboratively accelerate their development. On September 26, 2017, the staff held the second annual NRC Standards Forum, chaired by the NRC's Standards Executive. Approximately 60 attendees participated, representing SDOs: ASTM, ASME, ANS, American Concrete Institute, Institute of Electrical and Electronics Engineers, representatives from industry, Electric Power Research Institute (EPRI),

and technology working groups for non-LWRs. Several representatives from DOE and DOE national laboratories also participated.

This year, the forum addressed topics for both operating and advanced reactors. The presentations included identifying areas of interest for standards development, and facilitation and coordination among participants. Many new topics were identified in the advanced reactor sessions through a gap analysis funded by DOE on SFRs and a discussion of non-LWR developer needs from the technology working groups on MSRs, HGTRs, and fast reactors. Because there were a large number of areas where new or revised standards may be needed for advanced reactors, ANS proposed to take the lead in hosting a workshop to get into more detail and begin to prioritize standards development activities. The objective of the workshop, proposed for early CY 2018, is to create a strategic vision and plan for advanced reactors standards development. Standards forum participants, including representatives from the NRC, DOE, EPRI, and SDOs, agreed with this proposal.

Next Steps: ANS will work with the NRC and DOE to plan an advanced reactor codes and standards workshop in CY 2018. The tentative date is in May 2018. The NRC will continue to facilitate the identification of needed standards and participate in standards development activities and eventual endorsement of codes and standards when appropriate.

#### 5.2.4 The American Society of Mechnical Engineers/American Nuclear Society Non-Light Water Reactor Probabilistic Risk Assessment Standard Development

The ASME Joint Committee on Nuclear Risk Management (JCNRM), in coordination with ANS, issued the “Probabilistic Risk Assessment Standard for Non-LWR Nuclear Power Plants” as ASME/ANS RA-S-1.4-2013 for trial use in 2013. Source material from the existing ASME/ANS PRA standard ASME/ANS RA-Sa-2009, as revised in 2013 in ASME/ANS RA-Sb-2013 (Addendum B), as well as draft PRA standards under development by ANS 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. To support a diverse mixture of reactor concepts, including HTGRs, LMFRs, and MSRs, the standard is being developed on a reactor-technology-inclusive basis using established technology-inclusive risk metrics common to existing LWR Level 3 PRAs. Such risk metrics include frequency of radiological consequences (e.g., dose, health effects, and property damage impacts). To support a wide range of applications defined by the non-LWR stakeholders, the scope of this standard is very broad and is comparable to a full-scope Level 3 PRA for an LWR with a full range of plant operating states and hazards. Because some of the non-LWR designs supported by this standard include modular reactor concepts, this standard will include guidance for evaluating the integrated risk of multireactor or multiunit plants, including accidents on two or more reactor units or modules concurrently.

A number of national and international organizations are currently using the standard as they develop non-LWR PRAs and are providing valuable feedback to the JCNRM writing group for incorporation into the final draft of the standard. This writing group, which includes members of the NRC staff, met on September 12, 2017, and formulated a plan for updating the current version of the non-LWR PRA standard to be consistent with current versions of supporting standards and to reflect lessons learned from trial use activities.

Next Steps: The next edition of the standard is scheduled to be completed by the end of CY 2018. The NRC will review the 2018 edition for possible endorsement when it is available.

## 6.0 Strategy 5: Identify and Resolve Technology-Inclusive Policy Issues that Impact the Regulatory Reviews, Siting, Permitting, and/or Licensing of Non-Light Water Reactor Nuclear Power Plants

### 6.1 Overview

The identification and resolution of policy issues within the purview of the NRC contribute directly to regulatory predictability, effectiveness, and efficiency. Additionally, early identification and resolution of policy issues help to achieve the non-LWR Vision and Strategy Document objectives of enhanced technical readiness and optimized regulatory readiness and communications.

Technology-inclusive issues (i.e., those issues that apply widely to non-LWR designs, independent of the specific technologies used) have the broadest applicability for the non-LWR regulatory framework. Technology-specific non-LWR policy issues may be identified in the near term and will be addressed through design-specific regulatory engagement plans, as appropriate.

Issues for non-LWRs can range from strictly technical issues that can be resolved in accordance with existing policy, to technical issues that involve policy implications, to issues that are primarily matters of policy. The Commission is the ultimate decisionmaker on matters related to NRC policy. The actionable steps outlined in this strategy will assist the staff and stakeholders in determining which past policies apply to non-LWRs and whether there are new potential policy issues for non-LWRs to be examined.

### 6.2 Progress Summary

The list of policy issues the staff is considering with regard to the licensing of SMRs and non-LWRs is available on the NRC public Web site and is routinely revised to reflect the latest updates on each policy issue. The policy issues have been discussed in several of the recurrent 2017 stakeholder meetings and will continue to be discussed.

#### 6.2.1 Appropriate Source Term, Dose Calculations, and Siting for Small Modular Reactors and Non-Light Water Reactors

In the Commission memorandum dated December 29, 2011,[21] the staff stated it would remain engaged with SMR stakeholders on applications of mechanistic source term (MST) methods, review preapplication white papers and topical reports concerning source term issues it would receive from potential SMR applicants, discuss design-specific proposals to address MST, and consider research and development in this area. If necessary, the staff would propose revisions of guidance or regulations or propose new guidance to support application reviews of SMRs.

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[21] See Commission Memorandum, "Status of Staff Activities to Address Mechanistic Source Term Methodology and Its Application to Small Modular Reactors," dated December 29, 2011 (ADAMS Accession No. ML113410366).

In Commission memoranda dated May 30, 2013,[22] and June 20, 2014,[23] the staff provided updates on interactions with DOE and nuclear industry organizations about MST. The staff developed SECY-16-0012, "Accident Source Terms and Siting for Small Modular Reactors and Non-Light Water Reactors," dated February 7, 2016,[24] which concluded that (1) SMR and non-LWR applicants can employ modern analysis tools to demonstrate quantitatively the safety features of those designs, and (2) applicants can also use MST analysis methods to demonstrate the ability of the enhanced safety features of plant designs to mitigate accident releases.

Next Steps: As discussed in SECY-16-0012, the staff will engage with interested stakeholders on the siting proximity issue. This paper indicated that using MST analysis methods would also allow future combined license applicants to consider reduced distances to exclusion area boundaries and low-population zones, as well as potentially increased proximity of SMRs and non-LWRs to population centers.

The NRC staff developed a draft white paper[25] summarizing the assessment of current siting regulations, Commission policy, and staff guidance, and discussed it in a public meeting on December 14, 2017. The NEI Advanced Reactor Working Group is evaluating the NRC staff's white paper and coordinating discussions with developers and potential licensees. This topic will be discussed in a future periodic meeting. The staff will consider insights obtained from stakeholder discussions and determine whether clarifications to siting guidance or other actions would be beneficial to address siting criteria for SMRs and non-LWRs. As appropriate, the staff would then report to the Commission on proposed actions, as described in SECY-16-0012.

### 6.2.2 Emergency Preparedness Requirements for Small Modular Reactors and Other New Technologies

In SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors," dated October 28, 2011,[26] the NRC staff identified a possible approach for scalable emergency planning zones for SMRs. Subsequently, the staff liaised with other stakeholders (U.S. Department of Homeland Security/Federal Emergency Management Agency, U.S. Environmental Protection Agency, U.S. Department of State, U.S. Department of Commerce, NEI, ANS, and the public) to consider their recommendations.

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22 See memorandum to the Commission, "Current Status of the Source Term and Emergency Preparedness Policy Issues for Small Modular Reactors," dated May 30, 2013 (ADAMS Accession No. ML13107A052).

23 See memorandum to the Commission, "Status of Mechanistic Source Term Policy Issue for Small Modular Reactors," dated June 20, 2014 (ADAMS Accession No. ML14135A482).

24 See SECY-16-0012, "Accident Source Terms and Siting for Small Modular Reactors and Non-Light Water Reactors," dated February 7, 2016 (ADAMS Accession No ML15309A319).

25 See NRC draft white paper, "Siting Considerations Related to Population for Small Modular and Non-Light Water Reactors." November 2017 (ADAMS Accession No. ML17333B158).

26 See SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors," dated October 28, 2011 (ADAMS Accession No. ML112570439).

A Commission memorandum dated May 30, 2013,[27] provided updates on staff activities. The staff stated that it would not go further in proposing new policy or revising guidance for specific changes to emergency preparedness (EP) requirements absent specific proposals from the industry.

On December 23, 2013, NEI submitted a white paper on this topic.[28] The staff conducted a public meeting to discuss the white paper on April 8, 2014, and issued followup questions to NEI on June 11, 2014,[29] to which NEI responded on November 19, 2014.[30] The NRC did not endorse this white paper. On May 29, 2015, the NRC staff issued SECY-15-0077, "Options for Emergency Preparedness for Small Modular Reactors and Other New Technologies,"[31] which provided options for EP for SMRs and non-LWRs. The Commission issued the associated staff requirements memorandum (SRM) on August 4, 2015, which approved the staff's recommendation to initiate a rulemaking. The staff developed a notation vote paper as SECY-16-0069, "Rulemaking Plan on Emergency Preparedness for Small Modular Reactors and Other New Technologies," dated May 31, 2016,[32] which discussed the rulemaking plan and schedule. In an SRM dated June 22, 2016, the Commission approved the staff's plan and schedule for the rulemaking pertaining to EP for SMRs and other new technologies (ONTs) (such as non-LWRs and medical isotope production facilities). The rulemaking will disposition EP issues for future SMRs, non-LWRs, and ONTs. The Commission directed the staff to use exemptions in the interim (e.g., for the ongoing early site permit application from the Tennessee Valley Authority) until completion of the EP rulemaking. The NRC published the EP draft regulatory basis for SMRs and ONTs for public comment in the *Federal Register* on April 13, 2017. The staff held a public meeting May 10, 2017, and received stakeholder feedback on the draft regulatory basis. The public comment period closed on June 27, 2017, and the staff considered all stakeholder's comments in the final regulatory basis,[33] issued on October 16, 2017.

Next Steps: Rulemaking for EP for SMRs and ONTs is currently ongoing in accordance with Commission direction. A public meeting with the ACRS subcommittee is scheduled for

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27 See Memorandum to the Commission, "Current Status of the Source Term and Emergency Preparedness Policy Issues for Small Modular Reactors," dated May 30, 2013 (ADAMS Accession No. ML13107A052).

28 See NEI, "White Paper on Proposed Methodology and Criteria for Establishing the Technical Basis for Small Modular Reactor Emergency Planning Zone," dated December 23, 2013 (ADAMS Accession No. ML13364A345).

29 See NRC letter, "Questions on White Paper Describing Proposed Methodology and Criteria Regarding Small Modular Reactor Emergency Planning Zone," dated June 11, 2014 (ADAMS Accession Nos. ML14142A436 and ML14142A425).

30 See NEI letter, "Responses to Questions on White Paper on Small Modular Reactor Emergency Planning Zone," dated November 19, 2014 (ADAMS Accession No. ML14323A478).

31 See SECY-15-0077, "Options for Emergency Preparedness for Small Modular Reactors and Other New Technologies," dated May 29, 2015 (ADAMS Accession No. ML15037A176).

32 See SECY-16-0069 "Rulemaking Plan on Emergency Preparedness for Small Modular Reactors and Other New Technologies," dated May 31, 2016 (ADAMS Accession No. ML16020A388).

33 See NRC regulatory basis, "Rulemaking for Emergency Preparedness for Small Modular Reactors and Other New Technologies," dated October 16, 2017 (ADAMS Accession No. ML17206A265).

August 22, 2018, and the staff plans to provide the proposed rule to the Commission in October 2018.

### 6.2.3 Security and Safeguards Requirements for Small Modular Reactors and Non-Light Water Reactors

In SECY-11-0184, "Security Regulatory Framework for Certifying, Approving, and Licensing Small Modular Nuclear Reactors," dated December 29, 2011,[34] the NRC staff determined that the current regulatory framework is adequate to certify, approve, and license light-water SMRs, the manufacturing of SMR fuel, transportation of special nuclear material and irradiated fuel, and the interim storage of irradiated fuel proposed for light-water SMRs under 10 CFR Parts 50, 52, 70, 71, and 72, respectively. The staff also determined that security and material control and accounting requirements in 10 CFR Parts 72, 73, and 74, respectively, are also adequate. In the case of non-LWRs, the staff's preliminary conclusion was that the current security regulatory framework is comprehensive and sufficiently robust to certify, approve, and license non-LWRs.

On December 14, 2016, NEI submitted a white paper on a "Proposed Physical Security Requirements for Advanced Reactors Technologies."[35] This paper "proposes an approach to security that appropriately considers the enhanced safety and security incorporated into these designs and provides a more effective and efficient means to protect the public health and safety." In the transmittal letter, NEI requested that "the NRC establish regulatory positions on this approach and the associated policy and technical issues." NEI submitted a fee waiver request for the NRC's review of this white paper.[36]

The NRC approved NEI's fee waiver request and met with NEI and other stakeholders on May 3, 2017, to discuss the review of its submittal. The NRC provided feedback on NEI's white paper on July 21, 2017,[37] and NEI responded on September 8, 2017.[38] The NRC met with NEI and other stakeholders again on October 12, 2017, to discuss NEI's response and next steps. The staff prepared a draft white paper to facilitate stakeholder interactions.[39] The staff discussed this white paper with NEI and other stakeholders on December 13, 2017.

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34 See SECY-11-0184, "Security Regulatory Framework for Certifying, Approving, and Licensing Small Modular Nuclear Reactors," dated December 29, 2011 (ADAMS Accession No. ML112991113).

35 See "NEI white paper, 'Proposed Physical Security Requirements for Advanced Reactors Technologies,'" dated December 14, 2016 (ADAMS Accession No. ML17026A440).

36 See "Fee Exemption Request for NEI white paper, 'Proposed Physical Security Requirements for Advanced Reactors Technologies,'" dated December 14, 2016 (ADAMS Accession No. ML16350A088).

37 See "NRC Staff Comments/Questions on Advanced Reactor Physical Security White Paper," dated July 21, 2017 (ADAMS Accession No. ML17206A360).

38 See NEI response to "NRC Staff Comments/Questions on NEI White Paper, 'Proposed Physical Security Requirements for Advanced Reactor Technologies,'" dated September 8, 2017 (ADAMS Accession Nos. ML17263B131 and ML17263B142).

39 See "NRC Draft White Paper on Potential Changes to Physical Security Requirements for Small Modular and Advanced Reactors," issued November 2017 (ADAMS Accession No. ML17333A524).

Next Steps: The staff will consider stakeholder feedback and, as appropriate, plans to prepare a Commission paper in 2018 to address this issue.

### 6.2.4 Insurance and Liability for Small Modular Reactors and Non-Light Water Reactors

In SECY-11-0178, "Insurance and Liability Regulatory Requirements for Small Modular Reactor Facilities," dated December 22, 2011,[40] the staff identified a potential inequity between the insurance and liability regulatory requirements for power reactors producing electrical power equal to or greater than 100 megawatts electric (MWe) per unit and SMR designs with individual modules producing less than 100 MWe. For example, the staff raised the question of whether there would be insurance and indemnity coverage sufficient to pay all public claims in the case of an insurable event for an SMR with an individual module sized at less than 100 MWe under the current Price-Anderson Act and associated regulatory language.

Since completing that paper, the staff has prepared a comparative analysis of different SMR designs to further explore the potential inequity. The staff is using this analysis, and other inputs, to identify whether any changes are needed to the Price-Anderson Act for SMRs and non-LWRs. The staff is also evaluating the differences in potential consequences for postulated accidents for non-LWR designs in relation to insurance and liability requirements. The NRC staff engaged stakeholders on this topic during a November 2, 2017, public meeting and is awaiting industry feedback.

Next Steps: In accordance with the latest version of the Price-Anderson Act, the NRC will prepare a report to Congress, and an associated SECY paper, recommending the need for continuation or modification of the provisions of the Price-Anderson Act by December 31, 2021. Any changes that may be needed for non-LWRs and SMRs will be addressed by the staff in this report and SECY paper.

### 6.2.5 Containment Functional Performance for Non-Light Water Reactors

In SECY-93-0092, "Issues Pertaining to the Advanced Reactor (PRISM, MHGTR, and PIUS) and Candu 3 Designs and Their Relationship to Current Regulatory Requirements,"[41] issued April 8, 1993, the staff proposed to use a standard based upon containment functional performance to evaluate the acceptability of proposed designs rather than to rely exclusively on prescriptive containment design criteria. The staff also informed the Commission that it intended to approach this by comparing containment performance with the accident evaluation criteria. In SRM-SECY-93-0092, the Commission approved the staff's recommendation.

Subsequently, in SECY-03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs"[42] dated March 28, 2003, the staff recommended that the Commission approve the use of functional performance requirements to establish the acceptability of a containment or

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40 See SECY-11-0178, "Insurance and Liability Regulatory Requirements for Small Modular Reactor Facilities," dated December 22, 2011 (ADAMS Accession No. ML113340133).

41 See SECY-93-0092, "Issue Pertaining to the Advanced Reactor and Candu 3 Designs and their Relationship to Current Regulatory Requirements," dated April 8, 1993 (ADAMS Accession No. ML040210725).

42 See SECY-03-0047, "Policy Issues Related to Licensing Non-Light-Water Reactor Designs," dated March 28, 2003 (ADAMS Accession No. ML031770124).

confinement structure (i.e., a nonpressure-retaining building may be acceptable, provided the performance requirements can be met), and the staff proposed to develop functional performance requirements. In SRM-SECY-03-0047, dated June 26, 2003, the Commission disapproved the staff's recommendation, stating that there was insufficient information at the time for the Commission to prejudge the best options and make a decision on the viability of a confinement building. The Commission directed the staff to develop performance requirements and criteria, working closely with industry experts (e.g., designers, EPRI) and other stakeholders on options in this area, taking into account such features as core, fuel, and cooling systems design. The Commission also directed the staff to pursue the development of functional performance standards and then submit options and recommendations to the Commission on this important policy decision.

In SECY-05-0006, "Second Status Paper on the Staff's Proposed Regulatory Structure for New Plant Licensing and Update on Policy Issues Related to New Plant Licensing"[43] dated January 7, 2005, the staff discussed many of the concepts developed in previous communications between the staff and Commission on the topic of functional containment performance and, as directed in SRM-SECY-03-0047, outlined the attributes for a functional containment. The topic of functional containment was also addressed as part of the next-generation nuclear plant project in the context of MHTGRs. More recently, in light of the broad range of non-LWR designs under consideration, the staff has determined that it would be beneficial to seek Commission direction to support development and possible deployment of advanced reactor technologies. The staff plans to engage the Commission to confirm whether the Commission direction in SRM-93-0092 should be applied more broadly to additional advanced reactor designs (in addition to PRISM, MHGTR, and PIUS) and to propose a risk-informed, performance-based approach to establishing performance criteria for SSCs and corresponding programs to limit the release of radioactive materials from advanced reactors.

The staff has engaged stakeholders on this topic at several public meetings. The staff prepared a draft white paper on functional containment performance[44] to facilitate stakeholder interactions. The staff discussed this white paper with stakeholders on December 14, 2017.

Next Steps: The staff will consider stakeholder feedback and, as appropriate, plans to prepare a Commission paper in 2018 to address this issue.

## 7.0 Strategy 6: Develop and Implement a Structured, Integrated Strategy to Communicate with Internal and External Stakeholders Having Interests in Non-Light Water Reactor Technologies

### 7.1 Overview

This strategy supports the non-LWR Vision and Strategy objective for optimizing communications:

> The NRC will optimize its communication with non-LWR stakeholders by disseminating clear expectations and requirements for non-LWR regulatory

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[43] See SECY-05-0006, "Second Status Paper on the Staff's Proposed Regulatory Structure for New Plant Licencing and Update on Policy Issues Related to new Plant Licensing," dated January 7, 2005 (ADAMS Accession No. ML043560093).

[44] See "Draft White Paper, 'Functional Containment' Performance Criteria," dated November 30, 2017 (ADAMS Accession No. ML17334A155).

> reviews and oversight. These expectations and requirements will be expressed using multiple channels of communication appropriate to different stakeholder interests. The NRC messaging will be consistent and tailored to audiences for maximum communications effectiveness. Stakeholder feedback paths to the NRC will also be optimized to ensure that feedback is received, considered, and addressed in a timely manner, as appropriate.

Further, in the area of optimizing the NRC's communications, the near-term strategy is defined as follows:

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

The IAP for addressing communications consists of the following contributing activities:

- Provide timely, clear, and consistent communication of the NRC requirements, guidance, processes, and other regulatory topics and provide multiple paths for external feedback to the NRC.

- Develop consistent NRC messaging suitable to a range of audiences.

- Promote the exchange of non-LWR technical and regulatory experience with the NRC's international counterparts and industry organizations.

These contributing activities have begun and will continue throughout the process of implementing the non-LWR Vision and Strategy Document in all areas for non-LWR activities.

## 7.2 Progress Summary

The NRC has developed an internal communications strategy to guide activities in this area. The NRC has also proactively communicated with stakeholders and sought stakeholder feedback on all of its non-LWR readiness activities, starting with development of its Vision and Strategy Document and IAPs. The sections below describe several key communications accomplishments and ongoing activities.

### 7.2.1 The Department of Energy/U.S. Nuclear Regulatory Commission Workshops

The NRC must ensure that it has an effective means of exchanging information with its stakeholders, using a variety of channels and messages appropriate for target audiences. This information will range from general regulatory or industry topics of public interest to specific guidance for potential applicants to assist in preparing and presenting non-LWR applications for review by the NRC. An example of an effective communication exchange is the series of three workshops cohosted by the NRC and DOE. The staff also conducts periodic advanced reactor public meetings and participates in industry working groups, conferences, and other forums.

The NRC and DOE held the first Advanced Reactors Workshop on September 12, 2015; the second workshop on June 7–8, 2016; and the third on April 25–26, 2017. These workshops allowed key stakeholders to share perspectives, reach a common understanding, identify potential challenges, and explore opportunities. While these workshops were extremely

beneficial, the NRC has transitioned to having smaller, more frequent and focused interactions with stakeholders approximately every 6 weeks.

Next Steps: None; this action is complete.

### 7.2.2 Periodic Stakeholder Meetings

As discussed above, the NRC transitioned from the advanced reactor workshops to more frequent stakeholder meetings to discuss non-LWR topics of interest. These meetings are also made available for stakeholders to participate by phone and Webinar to maximize participation. The NRC has conducted 11 such meetings, beginning in July 2016. These meetings are in addition to several topic-specific NRC public meetings on topics such as the ARDC and consequence-based security.

Next Steps: Stakeholder meetings have been planned for approximately every 6 weeks in 2018. The first meeting in 2018 will take place on February 2, 2018.

### 7.2.3 Coordination with the Department of Energy

DOE created a vision and strategy[45] for the development and deployment of non-LWRs and established a goal of having at least two non-LWR designs reviewed by the NRC and ready for construction by the early 2030s. While DOE and the NRC have fundamentally different missions, as described in each organization's respective enabling legislation, it is in the best interests of all stakeholders to coordinate the non-LWR vision and strategy of both agencies. As such, the NRC aligned its non-LWR vision and strategy with DOE's non-LWR vison and strategy and plans to achieve its strategic goal of readiness to effectively and efficiently review and regulate non-LWRs by no later than 2025.

On November 10, 2016, the NRC and DOE signed a memorandum of understanding (MOU)[46] describing the roles, responsibilities, and processes related to the implementation of the DOE GAIN initiative. GAIN is an initiative that is intended to provide the nuclear energy community with increased access to the technical, regulatory, and financial support necessary to move new or advanced nuclear reactor designs toward commercialization while ensuring the continued safe, reliable, and economic operation of the existing nuclear fleet. As described in the MOU, the NRC is responsible for providing DOE and the nuclear energy community with accurate, current information on the NRC's regulations and licensing processes. DOE is responsible for then sharing that information with the prospective applicants, as appropriate. In addition to the specific activities identified in the GAIN MOU, the NRC actively participates in GAIN-sponsored non-LWR workshops, including the 2016 and 2017 Workshops on Molten Salt Reactor Technologies, the 2017 Nuclear Thermal-Hydraulics Workshop, the 2017 EPRI/GAIN Advanced Reactor Modeling and Simulation Workshop, the 2017 Fuel Safety Research Workshop, and the 2017 Molten Salt Chemistry Workshop. These workshops provide an opportunity for the NRC to gather information, develop technical expertise, and discuss NRC requirements and non-LWR readiness activities.

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[45] See DOE draft, "Vision and Strategy for the Development and Deployment of Advanced Reactors," dated May 27, 2016.

[46] See "Memorandum of Understanding Between U.S. Nuclear Regulatory Commission and U.S. Department of Energy on Gateway for Accelerated Innovation in Nuclear Initiative," dated November 10, 2017 (ADAMS Accession No. ML16215A382).

Next Steps: The NRC will continue to interact with DOE to gather information to inform the NRC's non-LWR readiness activities. The NRC will also continue to support the GAIN initiative, as specified in the GAIN MOU, and attend GAIN workshops and will continue to conduct periodic coordination calls with DOE and representatives from the Idaho National Laboratory who are managing the GAIN initiative.

7.2.4 Meetings and Conferences

In addition to the GAIN workshops discussed above, the NRC has actively participated in numerous workshops, conferences, and meetings to facilitate stakeholder outreach and communications related to non-LWRs. For example, the NRC participated in the following non-LWR events:

- EPRI Advanced Reactor Technical Advisory Group meetings
- Utility Working Conference and Vendor Technology Expo
- EPRI Workshop on Process Hazards Analysis to PRA for Advanced Reactors
- ANS annual meetings
- Nuclear Energy Insider's Annual International SMR and Advanced Reactor Summit
- NRC Regulatory Information Conference
- NRC Fuel Cycle Information Exchange
- Platts Nuclear Energy Conferences
- U.S. Nuclear Infrastructure Council's Advanced Reactor Technical Summits
- Idaho National Laboratory, Nuclear Energy Technology—Knowledge Transfer Workshop
- Nuclear Energy Advisory Committee meeting at Argonne National Laboratory
- National Governors' Association Workshop on the Future of Nuclear Power
- ORNL's Molten Salt Reactor Workshops
- IAEA and NEA workshops related to advanced reactors

Next Steps: The NRC will continue to participate in non-LWR meetings, conferences, and workshops as resources permit.

7.2.4 International Coordination

The NRC shares information and engages with various international groups, including the Organisation for Economic Co-operation and Development's NEA, IAEA, the Generation IV International Forum, and the NRC's international regulatory counterparts.

The NRC chairs NEA's ad hoc group for international regulators of non-LWRs, known as the Group on the Safety of Advanced Reactors (GSAR). The purpose of the group is to bring interested regulators together to discuss common interests, practices, and problems and address both the regulatory interests and research needs. Currently, Canada, China, France, Germany, Italy, Japan, Korea, Russia, and the United States are members of GSAR. The United Kingdom recently expressed interest in joining GSAR. Representatives from the European Union and IAEA also attend GSAR meetings. Initially, GSAR focused on SFR reactor safety and regulatory issues, such as severe accident prevention and mitigation and fuel qualification. However, GSAR plans to expand its scope to other types of non-LWR designs in the future. GSAR also interfaces with the Generation 4 International Forum (GIF). GIF representatives attend GSAR meetings and GSAR provides comments on GIF documents, such as SFR safety design guidelines.

The NRC also chairs the IAEA SMR Regulators Forum, which comprises representatives from Canada, China, Finland, France, Korea, Russia, and the United States. In this forum, interested regulators identify and address key regulatory challenges that may emerge in future SMR regulatory discussions. This forum focuses on issues that are applicable to both light-water cooled and non-LWR reactors, such as EP and DID.

Next Steps: The NRC will continue to exchange information with international counterparts and participate in NEA and IAEA working groups to foster international cooperation. The NRC will also explore bilateral interactions with countries such as Canada, where the same or similar designs (such as the Terrestrial MSR design) are being are being considered for licensing.