Technical, Licensing, and Potential Policy Issues for Micro-Reactors

In March 2010, the staff issued SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs," dated March 28, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML093290268), to inform the Commission of potential policy, licensing, and key technical issues that could require Commission consideration to support future design and license application reviews for light-water small modular reactors (SMRs). SECY-10-0034 also considered non-light-water reactor (non-LWR) designs, as appropriate. The staff has since resolved or is implementing plans for resolution of the issues discussed in that paper.[1] Subsequently, the staff developed "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," issued December 2016,[2] and the related implementation action plan dated July 12, 2017,[3] which described remaining issues related to licensing non-LWRs. In addition, Section 103 of the Nuclear Energy Innovation and Modernization Act (NEIMA) directs the U.S. Nuclear Regulatory Commission (NRC) to develop policies and guidance for the resolution of various policy issues.

This document discusses various topics that are particular to micro-reactors. Some of these are newly identified micro-reactor topics, and some have previously been considered in the context of SMRs or non-LWRs, but may need revisiting with the attributes of micro-reactors in mind. The staff's efforts to resolve policy issues broadly for non-LWRs may not adequately address the concerns of micro-reactor developers and future applicants. Design-specific issues will be addressed separately as they arise.

For each of the specific topics discussed below, the staff has included stakeholder views. In addition to the specific stakeholder views discussed below, the Union of Concerned Scientists (UCS) has expressed concerns with industry claims of enhanced safety of non-LWRs and micro-reactors that are pertinent to many of the topics discussed below. UCS has stated that they have "not identified any advanced reactor design that offers clear safety and security improvements over today's light-water reactors. In fact, some reactor concepts introduce new and significant safety and security issues." UCS is also concerned that "[s]ome advocates for micro-reactors underplay safety and security risks, asserting that the reactors are 'passively safe.' But passive safety systems are not infallible—especially with respect to sabotage—and no nuclear reactor is completely immune to meltdown."[4]

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1 NRC public Web page, "Small Modular Reactor and Non-Light Water Reactor Technical and Policy Issues," at https://www.nrc.gov/reactors/new-reactors/smr.html#techPolicyIssues.

2 See "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Headiness," dated December 21, 2016 (ADAMS Accession No. ML16356A670).

3 See "NRC Non-Light Water Reactor Near-Term Implementation Action Plans," dated July 12, 2017 (ADAMS Accession No. ML17165A069), and "NRC Non-Light Water Reactor Mid-Term and Long-Term Implementation Action Plans," dated July 12, 2017 (ADAMS Accession No. ML17164A173).

4 Testimony of Dr. Edwin Lyman, Union of Concerned Scientists, "DOE Modernization: Legislation Addressing Development, Regulation, and Competitiveness of Advanced Nuclear Energy Technologies" before the Committee on Energy and Commerce Subcommittee on Environment U.S. House of Representatives May 22, 2018.

1. Security Requirements

Current Regulation

As required by Title 10 of the *Code of Federal Regulations* (10 CFR) 50.34, "Contents of applications, technical information," and 10 CFR 52.79, "Contents of applications, technical information in final safety analysis report," applicants for operating licenses and combined licenses must submit security plans conforming with 10 CFR 73.55, "Requirements for physical protection of licensed activities in nuclear power reactors against radiological sabotage." In 10 CFR 73.55, the NRC requires that licensees "establish and maintain a physical protection program, to include a security organization, which will have as its objective to provide high assurance[5] that activities involving special nuclear material are not inimical to the common defense and security and do not constitute an unreasonable risk to the public health and safety." The NRC developed the requirements in 10 CFR 73.55 in consideration of the attributes of the current fleet of large LWRs, and they are prescriptive in some cases.

As with larger non-LWRs, some micro-reactor designs may use high-assay low-enriched uranium, which would be subject to the requirements associated with special nuclear material of moderate strategic significance under 10 CFR Part 73, "Physical protection of plants and materials," including requirements related to the transportation of high-assay low-enriched uranium fresh fuel.

Applicability to Micro-Reactors

The traditional approach to addressing the requirements of 10 CFR Part 73 has involved overlaying security provisions and features (e.g., fences, locked doors, guards) to protect the facility against the design-basis threat. Micro-reactors, as discussed here, will have much lower power levels, smaller site facility footprints, and generally simpler designs when compared with existing operating facilities licensed under 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." Micro-reactors are expected to more closely resemble higher-powered nonpower reactors in physical size, power level, fuel enrichment, and radionuclide inventory, and nonpower reactors are not subject to the same security requirements as traditional large power reactors.

As micro-reactors are still in varying developmental stages, the designers have a unique opportunity to determine how to address the design-basis threat (DBT) and to integrate physical and cybersecurity protections and material control and accounting measures within the design and associated programmatic controls. The staff anticipates that micro-reactor designers will integrate security considerations into the design consistent with the Advanced Reactor Policy Statement.[6]

The staff is conducting a limited-scope rulemaking to amend the NRC's physical security requirements for SMRs and other advanced reactor technologies. As discussed in SECY-18-0076, "Options for Physical Security for Light-Water Small Modular Reactors and

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[5] The concept of "high assurance" of adequate protection found in our security regulations is equivalent to "reasonable assurance" when it comes to determining what level of regulation is appropriate as stated in SRM-SECY-16-0073 – Options and Recommendations for the Force-On-Force Inspection Program in Response to SRM-SECY-14-0088," dated October 5, 2016 (ADAMS Accession No. ML16279A345).

[6] Volume 51 of the *Federal Register,* page 24643 (51 FR 24643) (1986), and 73 FR 60612 (2008).

Non-Light-Water Reactors" dated August 1, 2018 (ADAMS Accession No. ML18170A051), this rulemaking would establish voluntary alternative physical security requirements commensurate with the potential radiological consequences to public health and safety and the common defense and security. However, given the much smaller size and relative potential consequences of micro-reactors, other considerations may be appropriate for micro-reactors.

Stakeholder Perspectives

In a recently submitted white paper (ADAMS Accession No. ML19319C449), the Nuclear Energy Institute (NEI) stated that, "[f]or micro-reactors that can demonstrate that the potential consequences of accidents for the worst-case scenarios, would not lead to a significant adverse impact on the health or safety of the public, staff's ongoing rulemaking activities for the physical security for SMRs does not address all of the needed changes." NEI noted in its white paper that one of the biggest differences between nonpower reactors and large commercial reactors is that there is no DBT for nonpower reactors. NEI further stated that micro-reactor security should use a graded approach based on the amount of nuclear fuel and the potential health and safety consequences to the public. NEI suggested that the NRC should consider the requirements in 10 CFR 73.60, "Additional requirements for physical protection at nonpower reactors," and in 10 CFR 73.67, "Licensee fixed site and in-transit requirements for the physical protection of special nuclear material of moderate and low strategic significance," in lieu of the prescriptive requirements of 10 CFR 73.55. NEI suggested that micro-reactor security programs could focus on screening and training of personnel, access controls, intrusion detection, physical barriers to protect against theft and diversion, and communications with law enforcement. NEI noted that human actions may not be necessary to perform these functions, as they could be performed by automatic plant features. Other external stakeholders expressed similar views at a public meeting on October 17, 2019.

Staff Considerations

The physical security rulemaking underway for light-water SMRs and non-LWRs, though limited in scope, could provide micro-reactors with alternatives to several requirements related to physical security and provide a basis for further adapting security requirements for micro-reactors (through exemption requests). Provided that credible malicious acts can be shown to result in low or no significant releases, such analyses would justify applying alternative security measures (in accordance with 73.55(r)) or exemptions from requirements in 10 CFR 73.55 commensurate with risk. This would mean that an applicant for a micro-reactor would either need to protect against the design-basis threat in order to prevent radiological sabotage and offsite consequences or demonstrate through a consequence-based analysis that a range of credible malicious acts could not cause offsite consequences. Should the analyses conclude that offsite consequences are plausible, one approach could involve using similar review standards as nonpower utilization facilities with comparable consequences and augmenting where appropriate to meet security requirements for commercial micro-reactors. Staff will continue to evaluate graded approaches to physical protection and other requirements within the NEIMA-directed rulemaking for a technology-inclusive regulatory framework for advanced reactors.

2. Emergency Preparedness

Current Regulation

The emergency preparedness (EP) regulatory framework is primarily located in 10 CFR 50.47, 50.33, 50.34, 50.54, 50.72, 52.17, and 52.79 and Appendix E to 10 CFR Part 50. These regulations identify the specific items that emergency plans need to include and provide EP requirements for nuclear power reactors, including conditions of licenses and planning standards for onsite and offsite emergency response plans.

Applicability to Micro-Reactors

Existing EP regulations apply to licensing micro-reactors under the same framework as that for large LWRs, including establishment of an emergency plan that contains attributes to cope with emergencies. The NRC includes a specific provision for emergency planning zone (EPZ) size for smaller reactors under 10 CFR 50.47(c)(2), which states, "The size of the EPZs also may be determined on a case-by-case basis for gas-cooled nuclear reactors and for reactors with an authorized power level less than 250 MW thermal." In addition, the staff has developed a proposed rule that would create a new regulation (10 CFR 50.160) that defines an alternate, optional, performance-based approach to defining EPZs for SMRs and other new technologies, which would include micro-reactors.[7]

Stakeholder Perspectives

In both the October 17, 2019, public meeting and the NEI white paper, stakeholders stated that the draft proposed rule 10 CFR 50.160 appears to be flexible enough to accommodate micro-reactor design and licensing. However, stakeholders indicated that for facilities with potential consequences that are a small fraction of those for large LWRs, approaches applicable to nonpower reactors like NUREG-0849, "Standard Review Plan for the Review and Evaluation of Emergency Plans for Research and Test Reactors," issued October 1983, and Regulatory Guide 2.6, "Emergency Planning for Research and Test Reactors and other Non-Power Production and Utilization Facilities," might be more appropriate. NEI stated that the NRC should ensure that the regulatory guidance associated with the proposed rule 10 CFR 50.160 fully contemplates micro-reactor designs with very small potential consequences.

Staff Considerations

In staff interactions with stakeholders, micro-reactor designers have indicated that they may request exemptions related to current offsite and onsite emergency planning requirements. Additionally, micro-reactor stakeholders have participated in public meetings and Advisory Committee on Reactor Safeguards meetings with an awareness that the proposed EP rule to amend regulations for EP for SMRs and other new technologies likely provides a clear, optional path forward in regard to EP for potential micro-reactor applications. Provided facility consequences can be shown to be low and involve no significant releases, the staff can evaluate potential exemptions to EP requirements beyond the alternatives available in the proposed rule 10 CFR 50.160 on a case-by-case basis. One approach could involve using

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[7] See SECY-18-0103103, "Proposed Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies (RIN 3150-AJ68; NRC-2015-0225)," dated October 12, 2018 (ADAMS Accession No. ML18134A076), and the related staff requirements memorandum, and proposed rule published in *Federal Register* on May 12, 2020 (85 FR 28436).

similar review standards as for nonpower reactors with comparable consequences and modifying where appropriate for commercial micro-reactors. In the longer term, the staff is evaluating graded approaches to EP and other requirements within the NEIMA-directed rulemaking for a technology-inclusive framework for advanced reactors.

3. Staffing, Training, and Qualification Requirements

Current Regulation

The requirements in 10 CFR 50.47(b)(2), 50.54(m), 50.120, and Part 73 (related to staffing of security facilities, such as the central alarm station) govern varying aspects of reactor staffing. Staffing in this context refers to requirements on the number, training, and qualification of site personnel. As discussed in SECY-11-0098,[8] the staff has established guidance for the review of requests for exemptions from the licensed operator staffing requirements in 10 CFR 50.54(m). However, control room staffing represents only one portion of the total staffing complement required by other regulations.

Applicability to Micro-reactors

NRC's staffing requirements were developed for much larger facilities than micro-reactors and, in some instances, include prescriptive requirements that reflect assumptions which may not be applicable to micro-reactors. The current requirements for operator staffing outlined in 10 CFR 50.54(m) prescribe the number of operators required per unit and per control room. Recent NRC experience with the review of SMR designs has indicated that fewer reactor operators may be necessary per unit to safely operate these facilities than would have otherwise been required by regulation. Micro-reactors are smaller and generally simpler than the SMRs the NRC has reviewed recently, and they may be able to rely on inherent characteristics for safety functions. This degree of simplicity and inherent safety may result in few to no operator actions being credited for maintaining plant safety.

During preapplication discussions with the NRC staff, micro-reactor designers have indicated that they are evaluating whether the full set of tasks required for normal operation and accident scenarios can be accomplished by a more limited set of personnel on the site. In some cases, micro-reactor designers have proposed having no licensed operators. This may include using non-licensed personnel to perform functions that have historically been reserved for licensed operators (such as reactivity manipulations). Such cases would represent departures from existing practice for reactor facilities, given that the NRC has historically required licensed operators in the licensing of reactor facilities (both power and nonpower).

Stakeholder Perspectives

The role of licensed operators for micro-reactors has been a key focus area for stakeholders. Referencing the process used to determine appropriate operator staffing for SMRs (as outlined in SECY-11-0098), NEI stated in its recent white paper that much broader steps might be requested for micro-reactors. These steps were noted to potentially include not having operators at all or, alternatively, not having "at the controls" requirements, if "no operator actions are needed to protect the public health and safety." Furthermore, NEI discussed the potential of a facility having no control room, an approach that could result in the need to evaluate the

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[8] SECY-11-0098, "Operator Staffing for Small or Multi-Module Nuclear Power Plant Facilities" dated July 22, 2011 (ADAMS Accession No. ML111870574).

applicability of additional regulations, which reference either operators or a control room. For example, 10 CFR 50.34(f)(2)(iii) requires, in part, "…a control room design that reflects state-of-the-art human factor principles…"

Staff Considerations

As with recent proposals from light-water SMRs, the staff can use existing guidance, such as NUREG-1791 "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)" (ADAMS Accession No. ML052080125) to evaluate changes in staffing numbers, staff qualifications, or both. For micro-reactors, appropriately justified exemption requests may support licensed operator staffing requirements similar to those used for research and test reactors. Micro-reactor designers may also propose that no licensed operators are needed to fulfill safety functions. It should be noted that the number of facility staff and the qualifications of those staff are distinct matters that warrant specific and integrated consideration within the safety review of a design. Furthermore, the agency's process to evaluate such exemption requests, NUREG-1791, is predicated on the assumption that an applicant has a human factors engineering program that is capable of providing the necessary supporting analyses. As micro-reactor designers work toward reducing the number and role of plant personnel, this assumption may need to be reevaluated, and an alternative means for establishing an appropriate technical basis may be necessary.

The staff has confirmed that licensing facilities without licensed operators does not require a change to the Atomic Energy Act of 1954, as amended. In the absence of rulemaking to establish a new category of reactors that would not require licensed operators, exemptions from existing regulations would be necessary. Provided that accident consequences can be shown to be low and significant releases are unlikely to occur during the life of the facility, exemption requests could be considered on a case-by-case basis. Depending on the different licensing scenarios identified, policy issues may arise. For example, elimination of a requirement for licensed operators would have potential safety and enforcement implications for a range of responsibilities and authorities typically assigned, or reserved by regulation, to licensed personnel (e.g., emergency declarations, operability determinations, departures from license conditions or technical specifications). Accordingly, the staff is evaluating potential policy considerations associated with licensing reactors without licensed operators and will continue its interactions with stakeholders and prepare a separate paper in the future for the Commission on this topic.

4. Autonomous and Remote Operations

Current Regulation

The requirements in 10 CFR 50.54(i), (j), (k), and (m) address having a licensed operator at the controls during facility operation, require that only licensed operators manipulate controls that affect reactivity, and require that apparatus and mechanisms, other than controls, which may affect reactivity or power level be manipulated only with the knowledge and consent of an operator or senior operator.

Applicability to Micro-Reactors

In preapplication interactions, micro-reactor developers have expressed interest in the possibilities of autonomous and remote operation. One currently envisioned application for micro-reactors is as power production or backup power for remote locations, for example, on a

micro-grid, where the micro-reactor might be the primary source of power. Such applications would likely benefit substantially from the ability to let grid demand dictate reactor power without operator manipulation. This operational configuration, however, is precluded by the current regulations. Pursuant to 10 CFR 50.54(i)-(l), any operational change in reactor power level or reactivity may be performed only through a licensed operator manipulating the controls of the facility directly or through the manipulation of other apparatus and mechanisms as authorized by a licensed operator. Micro-reactor designers may also propose to operate or, in the case of autonomous reactors, monitor single or multiple micro-reactors from a remote location. Such cases raise the question of what requirements micro-reactor designers would need to meet for licensing individuals to monitor or operate a reactor from a remote location. The licensing of individuals for remote micro-reactor operations presumes developers have addressed applicable cybersecurity considerations for remote operation.

Stakeholder Perspectives

Stakeholders advocating micro-reactors cite reduced staffing, increased reliance on inherent reactor characteristics, possible remote operation, and possible autonomous operation as desirable attributes of this class of reactors. Developers may propose to rely upon various combinations of inherent reactor characteristics and design of the control and protection systems to support potential remote or autonomous reactor operations.

Staff Considerations

In general, autonomous and remote operations present means for reducing the overall reliance on human presence at reactor facilities. The potential opportunities afforded by these means of operation could include, for example, reductions in: (1) the need for plant operations personnel, (2) programs for the training and licensing of operators, and (3) instances of human operational errors challenging plant safety. At the same time, autonomous and remote operations raise potential policy-related matters. Autonomous operation necessitates evaluating the implications of reactivity operations being initiated and performed by automation rather than licensed operators, and potentially eliminating human operators as a diverse means of defense-in-depth for the assurance of reactor safety. In addition, micro-reactors that do not rely on operators to perform safety-related actions, and that can rely on autonomous operation, may have facility designs that do not include a control room from which individuals would be able to operate the facility. In this case, applicants would need to request, and the staff evaluate, justifications for, exemptions from 10 CFR 50.34(f)(2)(iii), which requires in part, that applicants provide for NRC review a control room design that meets state-of-the-art human factors engineering (HFE) principles.

Successfully licensing a facility with remote operation will require the staff to reassess its current practices related to HFE. Historically, the NRC and licensees have relied upon the ability of operators co-located with the reactor facility that they are controlling to receive sensory feedback in addition to the information provided to them through the plant's instrumentation and control interfaces. If such feedback is not available from within the main control room, it is most often readily obtained through direct inspection or through reports of field operators. Although such information is typically confirmatory information during normal operations, during off-normal conditions it can provide important diagnostic information that may not be otherwise available. This information can be particularly useful in conditions of instrumentation and control failures and in failures of highly automated systems. For advanced reactors, including those with simpler designs and greater use of passive or inherent safety features, such information may be of less importance but would need to be evaluated during the licensing review.

The staff has initiated work under contract with Brookhaven National Laboratory (BNL) to develop a method for scaling the scope and depth of HFE reviews for non-LWR technologies such as micro-reactors. The objective of this effort is to enable the staff to readily adjust the focus and level of staff HFE review efforts considering factors such as risk insights and the unique characteristics of the design or facility operation (including remote/autonomous operation). The ongoing BNL work, stakeholder engagement, and interactions with micro-reactor developers will help frame this issue and help the staff evaluate the need for future Commission engagement on this topic.

5. Regulatory Oversight

Current Regulation

In 10 CFR 50.70," Inspections," the NRC requires in part that a site licensed under 10 CFR Part 50 or 10 CFR Part 52 of this chapter, or a facility issued a manufacturing license under 10 CFR Part 52, provide adequate space to accommodate "a full-time inspector, a part-time secretary and transient NRC personnel." As described in NRC Inspection Manual Chapter (IMC) 2515, the NRC's Reactor Oversight Process for operating reactors includes resident inspectors at each site and baseline inspections of approximately 3,000 hours for a typical two-unit site.

Applicability to Micro-Reactors

Micro-reactors are expected to be substantially smaller and generally simpler, and, in the unlikely event of an accident, to pose a significantly reduced risk to the public. All these factors warrant the need to determine the appropriate level of regulatory oversight for micro-reactors as compared to other power reactors. The scope of the agency's oversight program including inspections and performance indicators will be different for micro-reactors due to differences in design and operations (e.g., total inventory of structures, systems, and components; conduct of operations and maintenance; operational support programs) and is likely to be substantially reduced, such that the number of inspection hours budgeted to the unit is closer to a nonpower reactor. Nonpower reactors do not have resident inspectors stationed at the sites, and similarly, the staff notes that there may not be a need for resident inspectors for micro-reactors.

Performance of the inspections themselves may also require revising existing practices. Micro-reactor designers that have interacted with the staff thus far have indicated the reactor unit is likely to be sealed for an extended period, rather than refueled as the existing power reactor fleet is on an approximately biannual basis. Micro-reactor developers are likely to include instrumentation and telemetry to support diagnostic evaluations and centralized support for multiple micro-reactor facilities. The NRC should capitalize on such technological advances to support remote inspection and monitoring of micro-reactors and to accomplish portions of the oversight program in a more efficient way. The NRC has started to leverage new technologies, as demonstrated through recent successful experience, to conduct remote inspections and monitoring using technology approaches during the response to the COVID-19 public health emergency.

Stakeholder Perspectives

Industry perspectives focus on how resident inspectors are likely not appropriate for micro-reactors. In the October 17, 2019, public meeting and the NEI white paper, stakeholders referenced the periodic inspections described in IMC 2545, "Research and Test Reactor

Inspection Program," as a more appropriate starting point for micro-reactors, and NEI states that "NRC should develop inspection procedures specifically for [micro-]reactors. The NRC's inspection manual and procedures should be performance-based and should be scalable to accommodate a variety of micro-reactors." NEI also expects that micro-reactor construction inspections would not resemble existing large nuclear power plant construction, as factory fabrication and substantially shorter timelines would be likely.

Staff Considerations

The staff is developing an appropriate oversight program in which monitoring and inspection will focus on those plant activities having the greatest impact on safety and overall risk. The oversight program would also address construction inspection. Considerations for the micro-reactor construction inspection program include: 1) leveraging lessons learned from the development of construction inspection procedures to support the 10 CFR Part 50 construction permit granted to Shine Medical Technologies Inc. for a medical radioisotope production facility, and 2) the need to address the use of factory fabrication for much of the facility and the shorter construction timelines expected for these facilities.

For the operational phase, the staff is considering whether to conduct periodic inspections of micro-reactors in a similar fashion to nonpower reactors, as appropriate. The scope and focus of inspection efforts developed to include structures, systems, and components and associated operational programs commensurate with their risk and safety significance. This activity will use insights from the development of IMC 2514, "AP1000 Reactor Inspection Program—Startup Testing Phase," and modification of IMC 2515, "Light-Water Reactor Inspection Program—Operations Phase," to accommodate the AP1000 plants at the Vogtle Electric Generating Plant. Additionally, the staff intends to explore insights from inspection and oversight activities in sectors outside of nuclear energy. During a May 7, 2020, advanced reactor public stakeholder meeting (ADAMS Accession No. ML20127H907), the staff provided a presentation on its intention to develop a framework document for advanced reactor inspection and oversight including for micro-reactors. The framework document will consider the topics identified above.

6. Aircraft Impact Assessment

Current Regulation

In 10 CFR 50.150, "Aircraft impact assessment," the NRC requires that each new power reactor applicant perform a design-specific assessment using realistic analyses of the effects on the facility of the impact of a large, commercial aircraft and show that, with reduced use of operator actions, the reactor core remains cooled or the containment remains intact and spent fuel cooling or spent fuel pool integrity is maintained.

Applicability to Micro-Reactors

In accordance with 10 CFR 50.150(a)(3), the aircraft impact assessment rule is applicable only to power reactors licensed after July 13, 2009 and does not apply to nonpower reactors. In the Statements of Consideration for the aircraft impact assessment rule, the Commission stated that core cooling, containment, spent fuel pool capability, and spent fuel pool integrity functions are applicable to LWRs, and each may not be applicable to non-LWR designs or may have to be supplemented by other key functions for non-LWR designs (Volume 74 of the *Federal Register*, page 28131 (74 FR 28131) (2009)).

Stakeholder Perspectives

In its white paper, NEI expressed the view that it is highly unlikely that an aircraft could impact a micro-reactor building or damage the fuel, and that the unmitigated consequences of an aircraft impact on a micro-reactor would not likely lead to a significant adverse impact on the health or safety of the public. As with the assessments of other topics, the lower expected consequences are due to the low radionuclide inventory of projected micro-reactors and the robustness of the designs in terms of retaining radionuclides within the reactor facilities under adverse conditions. NEI suggested that micro-reactors that are able to demonstrate the above performance should be eligible for an exemption from 10 CFR 50.150 supported by their demonstration that they meet the regulation in a different manner.

Staff Considerations

From a consequence perspective, the staff expects micro-reactors to more closely resemble nonpower reactors than large LWRs. Further, the site footprint of micro-reactors is likely to be substantially smaller than that of the existing power reactor fleet and the new reactors envisioned when the NRC promulgated the aircraft impact rule. Some micro-reactors might also be located underground, which could prevent a large commercial aircraft from striking safety-significant portions of a facility. A holistic risk-informed consideration of design-specific features, including the potential consequences of an aircraft impact, could provide a basis for meeting the underlying purpose of the rule and would be consistent with the Statements of Consideration, which stated that the NRC may need to issue exemptions and impose supplemental criteria for aircraft impact assessments of non-LWRs. Provided a micro-reactor applicant can make a case for demonstrating compliance with the rule, the staff expects that existing regulatory processes are sufficient to address micro-reactor applications in the near term. In the longer term, the staff will address this topic within the NEIMA-directed rulemaking for a technology-inclusive framework for advanced reactors.

7. Annual Fee Structure

Current Regulation

In 10 CFR Part 171, “Annual fees for reactor licenses and fuel cycle licenses and materials licenses, including holders of certificates of compliance, registrations, and quality assurance program approvals and government agencies licensed by the NRC,” the NRC stipulates the annual fee to be paid by power reactors.

Applicability to Micro-Reactors

The current annual fee structure in 10 CFR Part 171 would require micro-reactors to pay the same annual fee as those paid by the operating power reactor fee class. Although the NRC revised the fee rule in 2016 to establish a variable annual fee structure for SMRs, 10 CFR 171.5, “Definitions,” states that SMR, “for the purposes of calculating fees, means the class of light-water power reactors having a licensed thermal power rating less than or equal to 1,000 MWt [megawatts thermal] per module.” Therefore, the SMR fee provision excludes all non-LWR designs, regardless of size. Under 10 CFR Part 171, each micro-reactor would pay the same annual fee as an existing operating power reactor, even though the designs are expected to be considerably smaller in size and complexity.

Stakeholder Perspectives

During a June 18, 2020, public meeting, stakeholders identified this as a high-priority topic to be addressed (ADAMS Accession No. ML20169A590).

Staff Considerations

The staff plans to work within the existing rulemaking processes to propose and develop changes to 10 CFR Part 171 to provide non-LWRs with variable annual fees similar to those that the NRC would apply to light-water SMRs, with consideration of micro-reactors. The staff initiated stakeholder interactions during a May 7, 2020, public meeting, and will continue to engage with stakeholders this year to inform a proposed non-LWR annual fee policy which may be included in the fiscal year 2022 annual fee rule or a separate rulemaking.

8. Manufacturing Licenses and Transportation

Current Regulation

The regulations in 10 CFR 52.157, "Contents of applications; technical information in final safety analysis report," and 10 CFR 52.167, "Issuance of manufacturing license," govern the required information and conditions on the issuance of a manufacturing license. Specifically, 10 CFR 52.167 requires in part that "there is reasonable assurance that the reactor(s) will be manufactured, and can be transported, incorporated into a nuclear power plant, and operated in conformity with the manufacturing license, the provision of the Act, and the Commission's regulations."

Applicability to Micro-Reactors

Micro-reactors are sized such that integral manufacture of the nuclear portion of the reactor is a feasible approach, and some stakeholders have expressed interest in potentially pursuing a manufacturing license for their design. Deploying a micro-reactor may include manufacturing reactor components, fueling and testing the reactor in the factory, and then transporting the fueled reactor to a site. The staff discussed potential policy issues associated with manufacturing licenses in the enclosure to SECY-10-0034, which states the following:

> …the regulations for a manufacturing license granted in accordance with 10 CFR Part 52 are structured for a complete facility, including the NSSS [nuclear steam supply system] and balance-of-plant (BOP). This regulatory structure reflects the only experience the NRC has had with reviewing and issuing a manufacturing license (i.e., Offshore Power Systems' ML-1 for the Floating Nuclear Power Plant, issued in 1982). Issuing a manufacturing license authorizing the manufacture and transport of only major portions of the plant (e.g., the NSSS) and combining these with structures and systems built at specific sites may involve potential policy issues that would require Commission consideration.

SECY-10-0034 was written with SMRs in mind. In the case of micro-reactors, it is possible that the entire plant could be manufactured and transported to the site or major portions. In either case, guidance may need to be developed for implementing the

requirements for manufacturing licenses, and potential policy issues may arise, for example with regard to transportation of fueled reactors.

Stakeholder Perspectives

Stakeholders have expressed potential interest in manufacturing licenses; however, no entities have described definitive plans to develop applications using the related provisions under 10 CFR Part 52. Ongoing efforts by the U.S. Department of Energy (DOE) and the DOD to develop and test transportable so-called "mobile" micro-reactor designs could result in such concepts being proposed for NRC-licensed commercial uses in the future.

Staff Considerations

The staff is interacting with stakeholders and assessing the potential use of manufacturing license provisions with existing NRC regulations. If there is interest, then the staff would assess the need for guidance to implement the provision. The staff is also assessing how it could use various regulations related to possession of special nuclear material, manufacturing licenses, and transportation packages to support possible factory-like models for making, fueling, testing and moving micro-reactors. Depending on the different licensing scenarios identified, policy issues may arise. The staff could bring such issues before the Commission as specific policy issue or address them as part of proposed licensing decisions.

9. Population-Related Siting Considerations

Current Regulation

Regulations in 10 CFR Part 100, "Reactor site criteria," and Appendix A, "Seismic and geologic siting criteria for nuclear power plants," to 10 CFR Part 100 are applicable to all commercial nuclear power reactor sites, no matter the size or type of reactor. These regulations define several important requirements related to the proximity of a reactor to nearby residents in relation to population center distance, low population zone, and the exclusion area.

Applicability to Micro-Reactors

The exclusion area, low population zone, and population center distance associated with SMR, non-LWR, and micro-reactor sites could be smaller in size compared to those established for large LWRs based on reduced source terms. However, current guidance regarding siting considerations related to population density are currently not scalable. Accordingly, the staff has interacted with stakeholders to develop several options for the Commission's consideration to address population-related siting questions for advanced reactors. SECY-20-0045, "Population-Related Siting Considerations for Advanced Reactors," dated May 8, 2020 (ADAMS Accession No. ML19262H055), describes these options and the staff's recommendation. The staff developed SECY-20-0045 considering micro-reactor attributes; therefore, the NRC has not planned additional actions in the near term to address population-related siting requirements for micro-reactors.

10. Environmental Considerations

Current Regulation

The NRC provides environmental protection regulations applicable to its domestic licensing and related regulatory functions in 10 CFR Part 51, "Environmental protection regulations for domestic licensing and related regulatory functions." The regulations in Subpart A of 10 CFR Part 51 implement Section 102(2) of the National Environmental Policy Act of 1969, as amended (NEPA), in a manner that is consistent with the NRC's domestic licensing and related regulatory authority and that reflects the Commission's announced policy to take account of the regulations of the Council on Environmental Quality voluntarily, subject to certain conditions. In 10 CFR 51.20, "Criteria for and identification of licensing and regulatory actions requiring environmental impact statements," the NRC identifies licensing and regulatory actions that require the agency to issue an environmental impact statement (EIS) and notes that such actions must meet at least one of the following criteria:

- The proposed action is a major Federal action significantly affecting the quality of the human environment.

- The proposed action involves a matter that the Commission, in the exercise of its discretion, has determined should be covered by an EIS.

In 10 CFR 51.20(b) the NRC identifies issuance of a license to operate a nuclear power reactor as an action requiring an EIS. Issuance of a limited work authorization or a permit to construct a nuclear power reactor also require an EIS, as does issuance of an early site permit.

In 10 CFR 51.45, 51.49, 51.50, and 51.53, the NRC requires applicants to submit environmental reports with various new reactor applications.

Applicability to Micro-Reactors

In 10 CFR 51.45(b), the NRC requires applicants to take a graded approach to describing the environmental impacts as follows:

> The environmental report shall contain a description of the proposed action, a statement of its purposes, a description of the environment affected, and discussion of the following considerations: (1) The impact of the proposed action on the environment. Impacts shall be discussed in proportion to their significance…

The NRC would classify the designs being developed by most of the potential micro-reactor applicants with whom the staff has interacted as nuclear power reactors, which would therefore require preparation of one or more EISs during licensing depending on the licensing path selected. The graded approach suggests that these may not be as long or detailed as EISs prepared for larger reactors, because smaller facilities are likely to have less significant environmental impacts.

Stakeholder Perspectives

Potential applicants have provided the NRC staff with information during preapplication activities that suggest that micro-reactors may have substantially reduced environmental impacts when compared to large LWRs. Factors such as compact size and footprint, smaller radionuclide inventory, and inherent safety characteristics in micro-reactor designs could reduce the level of detail necessary in an applicant's environmental report and the staff's corresponding EIS. In addition, several white papers have been submitted by industry including a February 19, 2019, paper from Clearpath, "Advocating the use of Generic Environmental Impact Statements in Support of the Construction and Operation of Advanced Nuclear Reactors," (ADAMS Accession No. ML19059A426) and a March 5, 2020, paper from NEI, "NEI Recommendations for Streamlining Environmental Reviews for Advanced Reactors," (ADAMS Accession No. ML20065N155). The staff has considered these white papers and engaged with stakeholders on environmental topics for non-LWRs during several public meetings, including two workshops the staff held to inform its exploratory process to consider the viability of developing a generic environmental impact statement (GEIS) for advanced reactors. Public comments received during the GEIS exploratory process are discussed in a staff memorandum "Responses to Public Comments Received on the Exploratory Process for Advanced Nuclear Reactor Generic Environmental Impact Statement," dated March 4, 2020 (ADAMS Accession No. ML20044C854). The staff is considering comments from stakeholders recommending that the GEIS use a performance-based, technology-inclusive approach for analyzing the impacts of advanced reactors including, but not limited to, micro-reactors.

Staff Considerations

The staff is developing guidance for applicants and the staff that appropriately scales the depth and content of the environmental reports prepared by applicants and, subsequently, the environmental review efforts and EIS documentation prepared by the staff. The staff is developing this guidance based on the following considerations:

- acknowledgment of the expected design features and smaller size of advanced micro-reactors (e.g., reduced radionuclide inventories and enhanced safety features) when compared to large LWRs; and
- recognition that environmental impacts of micro-reactors could reduce documentation needed for impact areas.

The staff recently published draft Interim Staff Guidance (ISG) 29, "Environmental Considerations Associated with Micro-reactors," for comment (85 FR 11127) (2020), which discusses the staff's proposed implementation of its NEPA framework for advanced reactors. The guidance in this draft ISG clarifies how the NRC will approach environmental reviews for a micro-reactor application for a combined license, early site permit, construction permit, operating license, and limited work authorization. The guidance highlights unique considerations for micro-reactors in each resource area typically covered in the staff's environmental review. The draft ISG also offers guidance on identifying considerations and approaches to simplify and shorten the environmental reviews for micro-reactors relative to the environmental reviews that the NRC has previously performed for other nuclear facilities, such as large LWRs. The ISG outlines what the NRC staff considers to be an appropriate scope and level of detail for the specific aspects of an environmental review needed to document a micro-reactor licensing action. The ISG also outlines approaches to maximize a micro-reactor EIS's "incorporation by reference" of information from the staff's safety review, the applicant's

environmental report, and other relevant environmental documents, such as prior environmental work performed by DOE for projects initiated on DOE-controlled property.

The staff also prepared SECY-20-0020, “Results of Exploratory Process for Developing a Generic Environmental Impact Statement for the Construction and Operation of Advanced Nuclear Reactors,” dated February 28, 2020 (ADAMS Accession No. ML20052D175). In the SECY, the staff informed the Commission of its plans to develop a GEIS for advanced reactors with a power level up to approximately 30 MWth. Specifically, the staff plans to use a technology-neutral plant parameter envelope approach to better consider the diversity of anticipated advanced nuclear reactor designs while maximizing the number of issues that can be generically resolved within the GEIS to the extent feasible (see meeting slides from May 28, 2020, public meeting regarding the scope of the GEIS (ADAMS Accession No. ML20147A677)). In response to stakeholder feedback, the staff is now considering developing a plant parameter envelop that would better maximize the range of technologies that can reference the GEIS and largely eliminate the explicit reliance of power level for many areas within the environmental evaluation. In developing the GEIS, the staff must strike a balance between the range of designs considered and resolving the most issues in the GEIS, so that the GEIS will provide the benefit of streamlining the environmental review of an advanced reactor application. A future advanced nuclear reactor applicant would not need to meet the plant parameter envelope for all the resource areas in order to utilize the GEIS. Instead, an applicant could reference the GEIS resource areas that bound their application and then evaluate the resources areas that are not bounded. The staff issued the scoping summary report for the advanced reactor GEIS on September 25, 2020 (ADAMS Accession No. ML20260H180) and determined that development of the GEIS is viable. In response to Commission direction in SRM SECY 20-0020 (ADAMS Accession No. ML20265A112) to codify the advanced reactor GEIS, the staff is assessing schedule and resource implications and will inform the Commission of the results of this assessment.

The staff plans to continue with its current efforts to finalize ISG-029 and develop a GEIS for advanced reactors. These ongoing activities specifically account for the attributes of micro-reactors. As part of a longer-term effort, the staff is considering developing a rulemaking plan to address potential changes to Part 51 for Commission consideration including the use of environmental assessment to document environmental reviews instead of an EIS, as currently required by 10 CFR 51.20.