NRC Staff Prepared White Paper
"Micro-Reactor Licensing and Deployment Considerations:
Fuel Loading and Operational Testing at a Factory"
September 2023 Draft – Released to Support ACRS Interaction

THIS NRC STAFF WHITE PAPER HAS BEEN PREPARED AND IS BEING RELEASED TO SUPPORT INTERACTIONS WITH THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS). THIS PAPER HAS NOT BEEN SUBJECT TO NRC MANAGEMENT AND LEGAL REVIEWS AND APPROVALS, AND ITS CONTENTS SHOULD NOT BE INTERPRETED AS OFFICIAL AGENCY POSITIONS.

SUBJECT: Micro-Reactor Licensing and Deployment Considerations: Fuel Loading and Operational Testing at a Factory

PURPOSE:

The purpose of this paper is to support upcoming interactions with the Advisory Committee on Reactor Safeguard (ACRS) on options for regulating the fuel loading and operational testing of commercial factory-fabricated micro-reactors.

BACKGROUND:

The micro-reactors considered in this paper are commercial power reactors licensed under Section 103, "Commercial Licenses," of the Atomic Energy Act of 1954, as amended (AEA). Micro-reactors are expected to use non-light-water reactor technologies,[1] have thermal power levels on the order of several megawatts to a few tens of megawatts, and have small site footprints. They are also expected to have radionuclide inventories that would be about one percent or less of those for typical large light-water reactors and, in the unlikely event of an accident, are anticipated to have lower potential radiological consequences with a correspondingly lower impact on public health and safety. Micro-reactors may also have an increased reliance on passive systems and inherent characteristics to control power and heat removal.

In SECY-20-0093, "Policy and Licensing Considerations Related to Micro-Reactors," dated October 6, 2020 (Agencywide Documents Access and Management System Accession No. ML20129J985), the NRC staff identified several topics that should be addressed to support the licensing and regulation of micro-reactors. These topics include security; emergency preparedness; staffing, training, and personnel qualification; autonomous operations and remote operations; regulatory oversight; aircraft impact assessment; annual fee structure; manufacturing licenses and transportation; population-related siting considerations; and environmental considerations. Since the issuance of SECY-20-0093, the NRC staff has developed approaches to resolving several of these topics through ongoing work on rulemaking efforts including Title 10, "Energy," of the *Code of Federal Regulations* (10 CFR) Part 53, "Proposed Rule: Risk Informed, Technology-Inclusive Regulatory Frameworks for Commercial

[1] See "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," issued December 2016 (ML16356A670), for a discussion of non-light-water reactor technologies.

Nuclear Plants," dated March 1, 2023 (SECY-23-0021, ML21162A093); "Proposed Rule: Alternative Physical Security Requirements for Advanced Reactors," dated August 2, 2022 (SECY-22-0072, ML21334A003); and "Proposed Rule: Advanced Nuclear Reactor Generic Environmental Impact Statement," dated November 29, 2021 (SECY-21-0098, ML21222A044). These technology-inclusive rulemakings include proposed provisions that are scalable commensurate with the design features and risks posed by the various reactor technologies that could be subject to those rules. The proposed approaches in these rulemakings may be applied to micro-reactors. In addition, on August 14, 2023, the Commission approved a final rule in SRM-M230814, "Affirmation Session - SECY-22-0001: Rulemaking: Final Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies" (ML23226A216), that will provide alternative performance-based, technology-inclusive, risk-informed, and consequence-oriented emergency preparedness requirements for advanced reactors including micro-reactors. The NRC staff also issued the fiscal year 2023 fee rule (Volume 88 of the *Federal Register* (FR), page 39120 (88 FR 39120)) to provide fair and equitable fees for small modular reactors, including non-light-water reactors, by establishing new minimum and variable fees in recognition of the size and anticipated level of oversight for smaller reactors, including micro-reactors. Other initiatives are underway such as the development of the Advanced Reactor Construction Oversight Program as discussed in SECY-23-0048, "Vision for the Nuclear Regulatory Commission's Advanced Reactor Construction Oversight Program," dated June 6, 2023 (ML23061A086), which will consider a range of plant designs, including micro-reactor designs, to inform and scale the scope of construction oversight for advanced reactors.

DISCUSSION:

As the advanced reactor landscape continues to evolve, stakeholder interest in the deployment of factory-fabricated micro-reactors is increasing. The NRC staff is currently in preapplication engagements with several factory-fabricated micro-reactor developers that are considering novel deployment models. These models include loading fuel at a factory, operating the reactor for testing at a factory before deployment, transporting fueled reactors, replacing entire reactors at the deployment site rather than refueling there, and decommissioning or refurbishing and refueling reactors at locations away from the deployment sites. The NRC staff is prioritizing development of strategies to provide for the predictable and efficient licensing and regulation of these designs and operational models, and the identification and resolution of associated policy issues.

The NRC staff is cognizant that some topics and policy issues are more broadly relevant to the deployment of all types of micro-reactors and other reactor technologies, such as light-water small modular reactors and larger non-light-water reactors. Although this paper does not explicitly address such situations, the NRC staff will account for them, including through further Commission engagement, as appropriate.

The NRC staff engaged with stakeholders through the periodic advanced reactor stakeholders meetings in March and July 2023. During the meeting in March, the NRC staff presented topics it was considering including in the paper. During the meeting in July, the NRC staff presented the topics proposed for inclusion in the paper and provided preliminary information about the options the NRC staff was considering. Stakeholders provided oral feedback during these meetings, which the NRC staff considered during development of the paper. The NRC staff also released a draft white paper, "Micro-Reactor Licensing and Deployment Considerations: Fuel

Loading and Operational Testing at a Factory" (ML23236A598 and ML23236A597), on August 28, 2023, and held a related public information meeting on September 11, 2023, to provide clarity and transparency on the topics covered in this paper. The NRC staff also engaged with other Federal agencies, such as the Department of Energy, on the topics covered in this paper and its enclosure.

Factory-Fabricated Micro-Reactors

Factory-fabricated micro-reactors are a subset of micro-reactors that are expected to rely heavily on standardization of design features and mass production to simplify licensing and deployment. Some factory-fabricated micro-reactor designs may be "self-contained" in that they would incorporate the reactor, shielding, and balance of plant in one or several transportable containers and require minimal site preparation or construction activities at the deployment site.[2] Other designs may consist of a "core module" that comprises the core, reactor vessel, control elements, and other systems and components, which is fabricated in a factory and then incorporated into or connected to permanent structures and systems constructed at the deployment site, such as a reactor building and power conversion equipment. This paper uses the term "factory-fabricated module" to generically refer to the part of the eventual micro-reactor nuclear power plant that would be fabricated in a factory and that may be of either a self-contained design (i.e., a complete facility) or a "core module" design.

Factory-Fabricated Micro-Reactor Deployment Model

Conceptually, the deployment model for factory-fabricated micro-reactors will include various activities involving NRC licensing, certification, or approval. These activities may include design of reactors, manufacturing at a factory, loading fuel at a factory, operating the reactors for testing at a factory, transporting fueled reactors to deployment sites (whether loaded with unirradiated or irradiated fuel), operating the reactors for the production of electrical or heat energy at the deployment sites, replacing reactors at the deployment sites, transporting reactors away from the deployment sites at the end of their useful lives, decommissioning or refurbishing and refueling reactors at locations away from the deployment sites, and re-deploying refurbished reactors to deployment sites. Figure 1 depicts the generic deployment model considered by the NRC staff in this paper and the enclosure, which incorporates developers' publicly available information and stakeholder feedback. In contrast to this deployment model, some factory-fabricated micro-reactor developers may propose deployment models in which loading fuel or performing operational testing or both would occur at the deployment site, rather than at a factory.

[2] See 10 CFR 50.10, "License required; limited work authorization," for the activities defined as construction and requiring a permit or license issued by the Commission.

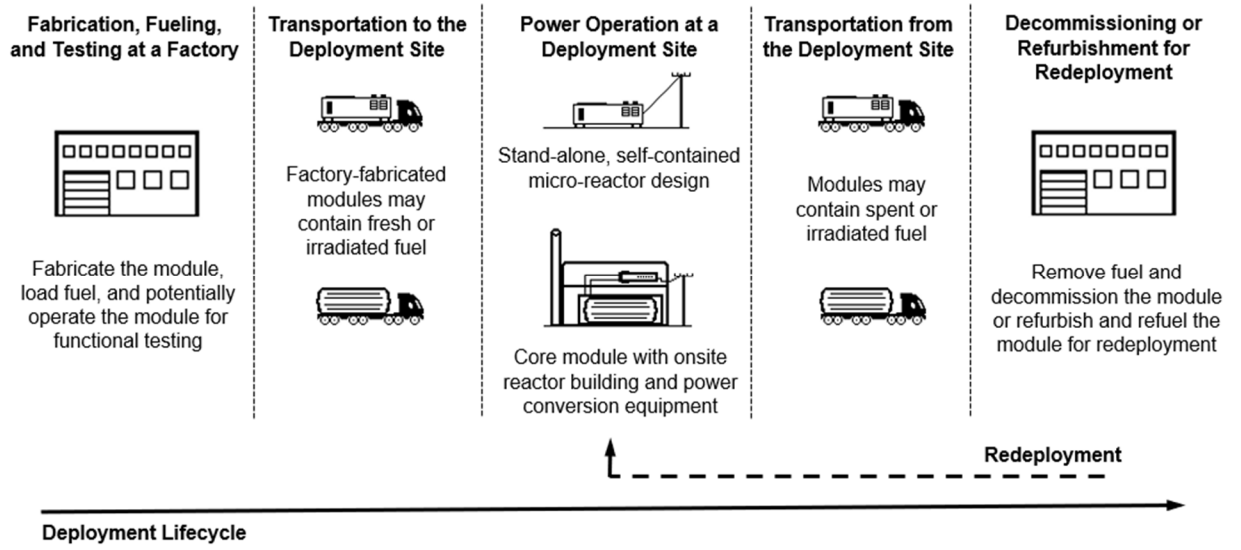

Figure 1: Generic factory-fabricated micro-reactor deployment model.

Deployment models could involve several other unique concepts not depicted in figure 1. These include construction activities at the deployment site that could be completed in days to weeks to a few months depending on the design, the arrival of prefueled reactors at the deployment site, remote reactor operations with few or no onsite reactor operators, autonomous reactor operation,[3] and the siting of reactors in densely populated locations. The enclosure to this paper describes these aspects, and the NRC staff's near-term strategies and next steps to address them, which may include further Commission engagement.

Based on early stakeholder feedback, the NRC staff assumes that a manufacturing license would be issued pursuant to Subpart F, "Manufacturing Licenses," of 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," for factory-fabricated modules because of the desired high degree of standardization and plans for mass production. The manufacturing license would satisfy the statutory requirements in AEA section 101, "License Required," that a license issued pursuant to AEA section 103 is required to manufacture, transfer, or possess a commercial utilization facility. The manufacturing license would approve the design of the factory-fabricated modules and manufacturing processes to be used at the factory. Specifically, 10 CFR 52.157, "Contents of applications; technical information in final safety analysis report," requires a manufacturing license application to describe "the applicant's proposed means of assuring that the manufacturing conforms to the design and to

[3] As discussed in detail in the enclosure, the term "autonomous operation" lacks a consistent definition across the various domains and contexts in which it is used. For the purposes of this paper, autonomous systems are considered those "… able to perform their task and achieve their functions independently (of the human operator), perform well under significant uncertainties for extended periods of time with limited or nonexistent communication, with the ability to compensate for failures, all without external intervention." (M. R. Endsley, "From here to autonomy: lessons learned from human–automation research," *Human factors*, Vol. 59, No. 1, pp. 5–27, 2017.)

reach a final conclusion on all safety questions associated with the design[.]"[4] The manufacturing license would also include provisions for transferring the modules to licensees authorized to receive them. In accordance with 10 CFR 52.173, "Duration of manufacturing license," a manufacturing license may be valid for not less than 5, nor more than 15 years from the date of issuance, with provisions for renewal.[5]

Under the current regulatory framework, loading fuel and performing operational testing at a factory would also require a facility operating license issued pursuant to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," or a combined license issued pursuant to 10 CFR Part 52 for a power reactor. Generally speaking, construction of the portions of the factory that are relied on to ensure the safety of fuel loading or operational testing of the modules as described in the 10 CFR Part 50 or 10 CFR Part 52 license application would be considered construction activities requiring a license under the regulations in 10 CFR 50.10(a). This paper presents an option in which fuel could be loaded into a module under a license issued pursuant to 10 CFR Part 70 without a 10 CFR Part 50 operating license or a 10 CFR Part 52 combined license. Under this option, the portions of the factory supporting fuel loading would be subject to the applicable requirements in 10 CFR Part 70. Although not explicitly addressed in this paper, portions of the factory subject to a 10 CFR Part 50 facility operating license, a 10 CFR Part 52 combined license, or a 10 CFR Part 70 license for special nuclear material, would also be subject to the relevant decommissioning requirements, including maintaining decommissioning funding assurance for micro-reactors operated for testing at the factory.[6]

If a vendor seeks to construct and operate reactors at the factory, numerous modules would likely need to be licensed because some deployment models envision mass production on the order of tens of modules per year or more. The NRC staff previously assessed alternative licensing structures for construction and operation of multi-module facilities under 10 CFR Part 50 and 10 CFR Part 52 in SECY-11-0079, "License Structure for Multi-module Facilities Related to Small Modular Nuclear Power Reactors," dated June 12, 2011 (ML110620459). The NRC staff reviewed the alternative approaches discussed in SECY-11-0079 and considers them to be, at a high level, potential strategies for how construction and operation of factory-

---

4 In accordance with 10 CFR 52.171, "Finality of manufacturing licenses; information requests," if an application references the use of a nuclear power reactor manufactured under 10 CFR Part 52, Subpart F, matters resolved in the manufacturing license proceeding would also be finally resolved in construction permit, operating license, and combined license proceedings, and hearings under 10 CFR 52.103, "Operation under a combined license." If the manufacturer also seeks licenses to operate the reactors at the factory (e.g., for testing), then the design issues that must be resolved for operation at the factory would largely overlap with the design issues to be resolved in a manufacturing license.

5 The NRC staff has proposed to amend this regulation to extend the maximum duration of manufacturing licenses from 15 years to 40 years, with provisions for renewal of additional periods of up to 40 years. See, "Proposed Rule: Alignment of Licensing Processes and Lessons Learned from New Reactor Licensing," dated June 6, 2022 (SECY-22-0052, ML21159A055).

6 There may be unique issues associated with the decommissioning process and decommissioning funding assurance for a reactor that is intended to be operated for a brief period at the factory under one license and then shipped to a deployment site for operation under a different license. The enclosure to this paper discusses the decommissioning process and decommissioning funding assurance for micro-reactors at deployment sites; some aspects of this discussion may be applicable to the factory site, as well. The NRC staff will further engage the Commission, as appropriate, on this issue.

fabricated micro-reactors may be licensed.[7] The NRC staff notes that there are differences between the licensing scenarios addressed in SECY-11-0079 and the scenarios for fuel loading and operational testing described in this paper. For example, the approaches for licensing shared systems required for performing operational testing of numerous individual factory-fabricated modules might be different than the approaches described in SECY-11-0079 for licensing shared systems required for operation of multi-module small modular reactor facilities. Micro-reactor developers that intend to use SECY-11-0079 to inform their licensing strategy for fuel loading or operational testing at a factory should address any such differences. Preapplication engagement with the NRC staff in this area may be beneficial.

The first alternative addressed in SECY-11-0079 was to issue a single license for a facility consisting of more than one modular reactor unit. There may be practical implementation challenges with this approach, as discussed in SECY-11-0079. Using this approach with a combined license for a reactor at a manufacturing facility would likely require the creation of an additional regulatory mechanism to address individual power reactor modules (e.g., a sublicense for each module). It would not be practical to use this approach with a 10 CFR Part 50 operating license for all modules to be manufactured, fueled, and operated for testing over the life of a factory because 10 CFR 50.57(a)(1) requires the NRC to find that construction of the facility, which would include construction of *all of the modules*, has been substantially completed as required before issuing an operating license that would allow operation of any of the modules. However, a single operating license could be useful for licensing fuel loading or operational testing of several modules that would be manufactured at about the same time.

The NRC staff also assessed a second alternative involving a possible hybrid of the single facility license and individual module license that would take the form of a master facility license and individual reactor module licenses. The NRC staff noted in SECY-11-0079 that "the NRC would need to develop processes and possibly new regulations to define how the master facility license would fit within the existing technical and legal requirements." The third alternative assessed in SECY-11-0079 was to issue a separate license for each reactor module.[8] The staff considered the third alternative to be "the best approach for the licensing of multi-module power reactor facilities." Under these strategies an applicant could also combine licensing requests for numerous modules in a single application, possibly to include modules intended to be refurbished, refueled, and potentially retested at the factory. The enclosure to this paper discusses these strategies further as they relate to licensing replacement reactors at deployment sites.

Legislative and Regulatory Considerations

The NRC staff assessed the current regulatory framework in 10 CFR Chapter I, the AEA, and the National Environmental Policy Act of 1969, as amended (NEPA). The options presented in this paper are potential regulatory approaches to fuel loading and operational testing of factory-fabricated modules that do not involve changes to regulations. The draft proposed rule package for 10 CFR Part 53 discusses and suggests requests for comments on fuel loading and operational testing and may result in rulemaking that provides longer-term ways to address

[7] Licenses for construction and operation would be in addition to the manufacturing license governing manufacture of the modules.

[8] These licenses might reference shared common elements (e.g., technical specifications), but such an approach could become complicated if there are design changes during manufacturing.

these issues for micro-reactors and other reactor technologies. In this paper, the NRC staff is considering near-term options that could be available before finalizing changes to NRC regulations.

A fundamental subject of this paper is whether the Commission's historical position that operation begins with the loading of fuel into the reactor is applicable to factory-fabricated modules.[9] As an outgrowth of this position, each factory-fabricated micro-reactor module that is fueled in the factory would be required to have a facility operating license or a combined license, regardless of whether it is operated for testing at the factory. This position also means that a factory-fabricated module would be considered to be "in operation" when loaded with fuel. The NRC's current regulatory framework does not provide for authorizing transportation of utilization facilities that are "in operation," meaning that a factory-fabricated module could not be transported to a deployment site when loaded with fuel without changes to the current regulatory framework. This paper includes an option under which a factory-fabricated module with features to preclude criticality would not be "in operation" when loaded with fuel.

The options discussed in this paper do not address security, emergency preparedness, fitness for duty, or access authorization requirements for the factory, the deployment site, a decommissioning facility, a refurbishment and refueling facility, or transportation of the reactor. As mentioned above, in SECY-20-0093, the NRC staff identified both security and emergency preparedness as topics that should be addressed for micro-reactors. The NRC staff recognizes that deployment models for factory-fabricated micro-reactors raise additional potential considerations that were not discussed in SECY-20-0093, including transportation security for fueled factory-fabricated modules and additional cybersecurity considerations for remote and autonomous operation (discussed in the enclosure to this paper). With respect to emergency preparedness, the staff believes that the risk-informed, performance-based emergency preparedness framework approved in SRM-M230814 can provide adequate protective measures. For security, the NRC has separate ongoing activities that would apply to micro-reactors, such as those associated with SECY-22-0072 and SECY-23-0021. In addition, the staff is developing options for Commission consideration related to security for special nuclear material, which it plans to provide in a Commission paper in October 2023. The NRC staff will consider whether additional Commission engagement on security or emergency preparedness requirements for factory-fabricated micro-reactor licensing and deployment is needed. As part of that consideration, the staff will evaluate whether there are regulatory gaps or areas of unnecessary regulatory burden for micro-reactors and, if appropriate, will provide recommendations to the Commission for addressing those challenges.

Options for Features to Preclude Criticality, Fuel Loading at a Factory, and Operational Testing at a Factory

The NRC staff identified fuel loading and operational testing at a factory as critical near-term policy issues that need to be addressed because they may impact micro-reactor deployment models. As mentioned above, features to preclude criticality that would allow the NRC staff to conclude that a factory-fabricated module is "not in operation" when loaded with fuel are integral

[9] See "Final Procedures for Conducting Hearings on Conformance With the Acceptance Criteria in Combined Licenses" (81 FR 43266, 43267) dated July 1, 2016, which states, "Consistent with the NRC's historical understanding, facility operation begins with the loading of fuel into the reactor."

to the viability of several of the options presented in this paper. Stakeholders are engaged in preapplication discussions with the NRC staff on these issues and have requested clarity on the available options as they develop licensing documents over the next several years to support deployment before 2030. The NRC staff notes that the options for fuel loading and operational testing are not mutually exclusive, and the Commission could direct the pursuit of more than one.

Topic 1: Features to Preclude Criticality

Features to preclude criticality would make a factory-fabricated module incapable of sustaining a nuclear chain reaction under any conditions, including single failures and common-cause failures. Such features could include, for example, bolts, locks, or welds to fix control elements in place; decoupling of control element drives so as to preclude insertion of reactivity; and additional fixed neutron absorbers. The installation and removal of these features would entail significant modifications to the module. The features to preclude criticality would be described in the design of the factory-fabricated module, which would be included in an application for a manufacturing license, standard design certification, or other permit or license.

Option 1a—Status quo

Under this option, the NRC would apply the Commission's historical position that operation of a reactor includes the loading of fuel (regardless of whether features to preclude criticality are installed) and consider a factory-fabricated module to be "in operation" when loaded with fuel. This would require the fabricator to hold a facility operating license issued pursuant to 10 CFR Part 50 or a combined license issued pursuant to 10 CFR Part 52 that authorizes operation in order to load fuel. Also, because the NRC's current regulatory framework does not provide for authorizing transportation of utilization facilities that are "in operation," under this option a factory-fabricated module could not be transported when loaded with fuel without changes to the current regulatory framework (e.g., establishing requirements for siting, licensed operators, operable safety-related systems, and environmental review for an operating reactor that is not at a fixed location).

Implementation

This option would not necessarily require NRC staff action to implement. However, to implement the options below in which fuel would be loaded at a factory, the NRC staff would need to develop alternative approaches to authorizing transportation of fueled modules, which might include significant changes to the NRC's regulations. The NRC staff did not consider changes to regulations in the development of this paper because this paper focuses on options that could be implemented in the near term (1-2 years) with fewer resources than those that would be required for rulemaking. If rulemaking were pursued in the future, it might be expanded to comprehensively treat a broader range of policy issues related to micro-reactors than those presented for Commission direction in this paper.

Advantages

- This option would not require NRC staff resources to develop guidance for features to preclude criticality.

- This option would maintain a consistent approach to licensing of all new reactors where fuel load is considered part of operation.

Disadvantages

- This option would present significant challenges to deployment models that include fuel loading in a factory because it would complicate compliance with the regulations for an operating reactor during transportation of a fueled module from a factory to a deployment site. The regulations for operating reactors are based on operation at a fixed site and would not be practical to implement for modules that are considered to be "in operation" during transport. For example, it might not be practical to ensure operability of active safety-related systems required for operation (e.g., the reactor protection system) during transport, and the current regulations do not contemplate such a situation.

- This option would require the fabricator to obtain a facility operating license or a combined license to load fuel into the reactor at the factory, even if the reactor is not further operated at the factory. There is a high regulatory burden associated with such a license, which does not accord with the level of risk posed by fuel loading (the discussion of Option 1b below explains the level of risk associated with fuel loading).

Option 1b—A factory-fabricated module with features to preclude criticality is not in operation when loaded with fuel

Under this option, a factory-fabricated module that includes features to preclude criticality would not be "in operation" when loaded with fuel. However, the factory-fabricated module would still be considered a utilization facility and require, at a minimum, a 10 CFR Part 52, Subpart F, manufacturing license to satisfy the statutory requirement in AEA section 101 that a license issued pursuant to AEA section 103 is required to manufacture or possess any commercial utilization facility.

The Commission has historically viewed operation as including the loading of fuel into the reactor. It took this view for reasons of safety based on recognition that loading fuel into and initial testing of a reactor involves a nuclear risk that would not otherwise be present.[10] In 1970, the Atomic Energy Commission (AEC) proposed a new regulation in 10 CFR 50.35, "Issuance of construction permits," to authorize the initial loading of nuclear fuel in the reactor core, *without attainment of a critical reaction*, under a construction permit.[11] To justify the proposal, the AEC

[10] In AEC-R 2/15, "Proposed Revision of 10 CFR, Part 50, Licensing of Production and Utilization Facilities," dated July 15, 1960 (ML21237A274) the Atomic Energy Commission (AEC) staff explained why it did not agree with a comment on the proposed rule suggesting that fuel loading and initial operational testing be authorized under a construction permit; the Commission did not adopt the commenter's suggestion.

[11] See the proposed rule at 35 FR 16687, October 28, 1970. Under this proposal, fuel loading under a construction permit would have been permitted only after the Commission found that that "such fuel loading

cited the "minimal" hazards associated with the loading of unexposed (unirradiated) fuel. The final rule issued in 1971 did not include the authority to load fuel under the construction permit because the comments received and further study by the AEC indicated that it would have little effect in reducing the time required for the completion of the licensing process and might complicate AEC licensing procedures.[12]

Features to preclude criticality would ensure that a factory-fabricated module would not attain criticality with significant margin and that the potential hazard associated with loading fuel would be even less than the "minimal" hazards for fuel loading of reactors without such features that were previously considered by the AEC as a potential justification for authorizing fuel loading without an operating license. Further, with features to preclude criticality and all criticality safety controls required by 10 CFR Part 70 in place, the presence of fuel in the module would not create a nuclear hazard different than the presence of the same fuel in a storage location or container licensed under 10 CFR Part 70. Therefore, licensing fuel load at the factory under 10 CFR Part 70 would adequately protect safety, as discussed below in the options for loading fuel at a factory.

The NRC staff also notes that in contrast to the AEC's reasons for ultimately not authorizing fuel load under a construction permit, loading fuel in a factory without an operating license or combined license could improve regulatory efficiency of licensing and deployment of factory-fabricated micro-reactors without a reduction in safety. In addition, Option 1b would facilitate transport of fueled factory-fabricated modules that could have overall safety benefits for factory-fabricated micro-reactor deployment. These benefits might include handling fuel for many reactors in the controlled environment of the factory such that operating experience would rapidly accumulate, as opposed to fuel handling at many deployment sites where such fuel handling would be an unusual evolution. Another benefit could be the manufacturer's ability to identify and correct defects or operational issues at the factory, which would avoid having to transport modules back and forth between the deployment sites and the factory if such defects or issues were identified at deployment sites.

When features to preclude criticality are present, the NRC staff is considering whether it would be appropriate that operation begins with the removal of those features. The NRC staff considers the removal of features to preclude criticality to be the best analogue to initial loading of fuel for reactors without such features because both are distinct actions that put a fully constructed utilization facility in a position to sustain a nuclear chain reaction, and in both cases, the utilization facility cannot sustain a nuclear chain reaction (for lack of sufficient reactivity) until the action takes place. This could address requirements in the AEA, 10 CFR Part 50, and 10 CFR Part 52 that must be satisfied before the reactor is placed into operation or that are premised on the reactor being in operation.

For example, section 185b. of the AEA states, in part, that "[f]ollowing issuance of the combined license, the Commission shall ensure that the prescribed inspections, tests, and analyses are performed and, prior to operation of the facility, shall find that the prescribed acceptance criteria are met." Under the Commission's historical position that fuel loading is part of operation, a

---

will not be inimical to the common defense and security or to the health and safety of the public," based, in part, on satisfactory performance of the preoperational testing program.

[12] See the final rule at 36 FR 8861, May 14, 1971.

reactor that arrives at the deployment site loaded with fuel would be "in operation" before the Commission makes the required finding that the prescribed acceptance criteria are met. The approach under consideration by the staff would avoid the situation in which a fueled reactor arrives at the deployment site and is already considered to be "in operation." Removal of the features to preclude criticality, and the resultant entering of the facility into operation, would not be authorized until the Commission finds that the prescribed acceptance criteria are met and the public is given an associated opportunity to request a hearing on whether the facility satisfies the acceptance criteria.

Similarly, the approach being considered by the staff would allow a construction permit holder for the deployment site to receive a fueled factory-fabricated module that included features to preclude criticality. Removal of the features to preclude criticality would not be allowed until the NRC issues a 10 CFR Part 50 facility operating license after making the operating license findings required by AEA 185a. and providing the associated opportunity for hearing required by AEA section 189a.(1)(A).

The NRC staff also considered potential complications to the current licensing procedures and regulations that may be associated with the recommendations in this option. Certain requirements in the AEA and 10 CFR Parts 50 and 52 use initial fuel load as a regulatory milestone. Depending on the specific wording of the relevant requirement, there may be complications caused by a factory-fabricated module arriving at the deployment site already loaded with fuel, as explained below.

For combined licenses, section 189a.(1)(B)(i) of the AEA requires, in part, that "[n]ot less than 180 days before the date scheduled for initial loading of fuel into a plant by a licensee that has been issued a combined construction permit and operating license under section 185b., the Commission shall publish in the Federal Register notice of intended operation." Section 189a.(1)(B)(i) further requires that this notice provide a 60-day period in which to request a hearing "on whether the facility as constructed complies, or on completion will comply, with the acceptance criteria of the license."[13]

In the case where a fueled factory-fabricated module arrives at a deployment site for which a combined license has been issued, the fabricator would have loaded fuel at the factory ***under its license***. Therefore, *at the deployment site* there would not be "initial loading of fuel into a plant *by a licensee that has been issued a combined construction permit and operating license*" (emphasis added). Under a plain language reading of the entry condition in AEA section 189a.(1)(B)(i), this situation would not trigger its requirements. However, the apparent purpose of the provision is to offer the hearing opportunity at least 180 days prior to when the fuel is loaded and ready for use at its authorized location. It would be contrary to that purpose if, in this situation, the Commission did not publish the notice of intended operation and opportunity for the public to request a hearing on conformance with the acceptance criteria in the combined license for the deployment site. To fulfill the underlying purpose of the law, the NRC staff considers that the removal of features to preclude criticality would be the best analogue to initial

[13] The statutory reference to the "acceptance criteria of the license" presupposes that the license has been issued. However, it is possible that the micro-reactor would be fabricated and fueled prior to issuance of the combined license for the deployment site.

fuel load by the combined license holder for the reasons stated previously. In this case, the NRC would time its publication of the notice of intended operation based on the scheduled date for removal of features to preclude criticality by the combined license holder for the deployment site.[14]

The regulations in 10 CFR Part 52, Subpart C, contain requirements related to initial fuel load. For example, the regulations in 10 CFR 52.103(a) require that "[t]he licensee shall notify the NRC of its scheduled date for initial loading of fuel no later than 270 days before the scheduled date and shall notify the NRC of updates to its schedule every 30 days thereafter." There are numerous other regulations including 10 CFR 50.47, 10 CFR 50.54, 10 CFR 50.55a, 10 CFR 50.71, 10 CFR 50.75, 10 CFR 50.120, 10 CFR Part 50 Appendix E, 10 CFR Part 50 Appendix J, 10 CFR 52.99, and other provisions in 10 CFR 52.103 where initial fuel load is used as a milestone. The appropriate approach to these regulations depends on their wording. An applicant for or holder of a combined license could request exemptions from those regulations that cannot be complied with as written, so long as the requested exemptions satisfy the AEA and the regulatory requirements for an exemption. License conditions may be needed to address any regulatory gaps.

Several of the options and approaches discussed in this paper are predicated on the inclusion of features to preclude criticality. Under one option, the holder of a manufacturing license could load fuel in a module that includes features to preclude criticality under a 10 CFR Part 70 license without obtaining a 10 CFR Part 50 operating license or a 10 CFR Part 52 combined license. Under another option, the holder of a manufacturing license could obtain additional licenses under Parts 50 or 52 to permit operational testing of the reactor at specified reactor powers up to and including full power. Also, after operation (whether at the factory for testing or at the deployment site for power production), features to preclude criticality could be reinstalled to take the module out of operation and facilitate transportation of the fueled module.

Features to preclude criticality would allow for transportation of a fueled module under the current regulations because the module would not be "in operation" during transport. The module could be covered by provisions in the manufacturing license that allow for transfer to a licensee authorized to acquire the module, while the radioactive material in the module would be controlled by materials licenses and the existing transportation regulations in 10 CFR Part 71, "Packaging and Transportation of Radioactive Material." The enclosure to this paper describes the NRC staff's near-term strategy for reviewing packages for the transport of factory-fabricated modules that are loaded with fuel under 10 CFR Part 71. In accordance with the NRC and U.S. Department of Transportation regulations, the package contents would be the responsibility of the shipper (factory licensee) and potentially the carrier until receipt by the deployment site licensee.

[14] The NRC staff's recommendation would also address the reference to fuel load in Section 189a.(1)(B)(v) of the AEA: "The Commission shall, to the maximum possible extent, render a decision on issues raised by the hearing request within 180 days of the publication of the notice provided by clause (i) or the anticipated date for initial loading of fuel into the reactor, whichever is later." The NRC staff understands "anticipated date for initial loading of fuel into the reactor" in context to refer to the scheduled date for initial loading of fuel by the COL holder that is discussed in AEA Section 189a.(1)(B)(i).

The draft proposed 10 CFR Part 53 rulemaking package discusses and requests comments on an alternative theory for dispensing with an operating license or combined license for factory fuel loading under which the module would not be considered a utilization facility. The NRC staff is not pursuing this alternative under the current regulatory framework in 10 CFR Parts 50 and 52.

Implementation

The NRC staff would implement this option using the existing regulations for utilization facilities by developing guidance for including features to preclude criticality in factory-fabricated modules. Some exemptions may be required to implement this approach. For example, there are regulations that use “initial fuel load” or other activities or events as the milestones by which certain operational programs must be implemented or reports submitted. Exemptions or other appropriate regulatory vehicles may be needed to substitute other activities or events, such as the removal of features to preclude criticality, for the current milestones in the regulations.

The NRC staff will consider an appropriate regulatory vehicle to more formally establish the positions in Option 1b that fueled micro-reactors with features to preclude criticality are not in operation, that operation in these circumstances begins with the removal of those features, and that the removal of those features is the best analogue to “initial loading of fuel” for a reactor without such features. The staff will seek further Commission direction, as necessary.

Advantages

- This option would allow for safe, efficient, and novel approaches for licensing fuel loading in a factory-fabricated module without requiring a facility operating license or combined license and for regulating the safe transport of fueled modules without a rulemaking to establish requirements for transportation of utilization facilities that are in operation.

- This option would provide a predictable regulatory framework for fuel loading and transport of fueled factory-fabricated modules that would be available for use by developers in the near term.

- This option would provide a clear milestone for the beginning of operation to allow the Commission to make all required notifications and findings prior to a factory-fabricated micro-reactor being placed into operation at the deployment site. It would also provide transparency and clarity for the public to participate in hearing processes related to licensing at the deployment site.

Disadvantages

- The NRC staff would need to develop technology-inclusive guidance on the use of features to preclude criticality for fuel loading in the factory and transportation of fueled modules.

Topic 2: Fuel Loading at a Factory

Some factory-fabricated micro-reactor developers have indicated that fuel loading at the factory and transportation of fueled modules to the deployment sites may be essential for their deployment models. Depending on the reactor design, fuel loading and any subsequent fabrication steps, such as closing the reactor vessel, may require expertise and specialized equipment that would be inefficient or impractical to make available at each deployment site. The following options apply to authorization of fuel loading only and not to operational testing.

Option 2a—Authorize fuel loading at the factory under a power reactor license

This option would be consistent with the Commission's historical position that reactor operation commences with the loading of fuel. Under the current regulatory framework and this historical position, each factory-fabricated module that would be loaded with fuel at the factory would be required to have a facility operating license or combined license issued pursuant to AEA section 103 before loading fuel. A manufacturing license would allow the manufacture of unfueled reactors, but it would not authorize fuel loading or any other aspect of operation, decommissioning, or the possession of special nuclear material.

Option 2a would designate each factory-fabricated module and potentially certain portions of the factory as a utilization facility and require the fabricator to obtain a facility operating license or a combined license for a nuclear power reactor and to have appropriate licensed personnel to load fuel. To issue a combined license under 10 CFR Part 52, the NRC staff would need to prepare a safety evaluation report and an environmental impact statement (EIS), the ACRS would have to review the application, and the mandatory hearing and any contested hearing would need to be held. For each of these steps, the NRC could consider all contemplated combined licenses together in one application. For operation under a combined license, AEA section 185b. requires that the NRC find that the acceptance criteria in the inspections, tests, analysis, and acceptance criteria (ITAAC) for that reactor are met before the reactor may begin operation. Section 189a.(1)(B) of the AEA requires the NRC to provide an opportunity for a hearing on conformance with the acceptance criteria at least 180 days before the scheduled initial fuel load. Because modules may be fabricated in much less than 180 days, this hearing opportunity may be noticed before beginning the fabrication of the subject module.

To operate a reactor under 10 CFR Part 50, a person must first obtain a construction permit and then an operating license. Issuance of a facility construction permit under 10 CFR Part 50, which could cover multiple reactors, would require an EIS, review by the ACRS, and completion of a mandatory hearing and any contested hearing. To issue a 10 CFR Part 50 operating license under the current regulatory framework, the NRC staff would need to prepare a safety evaluation report and a supplement to the construction permit EIS, the ACRS would have to review the application, and any contested hearing would need to be held. As described in the enclosure to this paper, the timeframe to complete a contested hearing and environmental review for issuance of a 10 CFR Part 50 operating license could be about 24 months or less. These actions could be initiated upon submission of each operating license application well in advance of beginning construction of each module. To some degree, these activities could be consolidated for several or all modules contemplated by the fabricator using the multi-module licensing strategies in SECY-11-0079 previously described in this paper.

Whether licensed under 10 CFR Part 50 or 10 CFR Part 52, the licensee would need to implement operational programs for matters such as security, emergency preparedness, fitness for duty, and operator training and qualification. As described in SECY-20-0093, the Commission could use regulatory vehicles including exemptions, hearing orders, or rules of particular applicability to adjust the amount of information to be submitted in a license application and the NRC staff review necessary to issue a license that authorizes fuel load but not additional operation. For example, for a factory-fabricated module for which the manufacturer is not authorized to undertake operational activities beyond fuel loading, it may not be necessary for the licensee to implement certain operational programs and technical specifications. However, the AEA mandates certain requirements such as hearings, ITAAC (for Part 52), and review by the ACRS for the issuance of any license to construct and operate a commercial utilization facility, regardless of the nature of the safety review.

Implementation

The NRC staff could appropriately risk-inform reviews and develop processes for efficient reviews of applications for licenses that would authorize only fuel load and not additional operation of factory-fabricated modules. The specific reviews supporting factory-fabricated modules could take advantage of other actions on the subject design such as a related manufacturing license and, where applicable, other certifications and approvals. Implementation of this approach may include additional Commission engagement, particularly if hearing orders or rules of particular applicability are used.

Advantage

- This option relies on established processes for the licensing of nuclear reactors. The existing technical guidance related to 10 CFR Part 70 could be used to risk-inform the review of a license application for fuel loading under this approach due to the expected similarities between handling special nuclear material under a 10 CFR Part 70 license and loading fuel in a factory-fabricated module under a 10 CFR Part 50 or 10 CFR Part 52 license limited to fuel loading without additional reactor operation.

Disadvantages

- There is a high regulatory burden associated with requiring the reactor manufacturer to obtain a facility construction permit and operating license or a combined license for the sole purpose of fuel load in light of the minimal risk posed by that activity alone.

- Manufacturers will likely seek to accelerate the timeframes for authorization to load fuel under a 10 CFR Part 52 combined license by submitting the notifications and schedules related to ITAAC completion required by 10 CFR 52.99, “Inspection during construction; ITAAC schedules and notifications; NRC notices,” as early as possible for each factory-fabricated module. This could result in noticing intended operation and the related hearing opportunity before the start of fabrication of a module. Similarly, a manufacturer might submit a 10 CFR Part 50 operating license application and the NRC might issue the related notice of opportunity for hearing before construction of a module begins.

Option 2b—Authorize fuel loading at the factory under a 10 CFR Part 70 license

This option would provide an approach for loading fuel at the factory without requiring a facility operating license under 10 CFR Part 50 or a combined license under 10 CFR Part 52 for a factory-fabricated module. Instead, a manufacturing license would authorize possession of the module, and loading fuel would be authorized and conducted solely under a license issued pursuant to 10 CFR Part 70 for possession of special nuclear material. This option relies on the use of features to preclude criticality described in Option 1b so that the factory-fabricated module with features in place to preclude criticality would not be "in operation" when loaded with fuel and would not require a 10 CFR Part 50 facility operating license or a 10 CFR Part 52 combined license to load fuel.

Under this option, a manufacturer could combine an application for a 10 CFR Part 70 license for fuel loading with an application for a 10 CFR Part 52 manufacturing license consistent with 10 CFR 52.8, "Combining licenses; elimination of repetition." The application would include the information required by 10 CFR 70.22, "Contents of applications," including the technical qualifications of the manufacturer to engage in fuel loading activities in accordance with applicable regulations and a description of the equipment and facilities and the proposed procedures for protecting health and minimizing danger to life or property. The application would also include criticality safety controls required by 10 CFR Part 70 for factory operations (e.g., fuel storage, fuel handling, loading fuel in a module) which may be different than or in addition to the features to preclude criticality included in the factory-fabricated module that would be described in the manufacturing license application. Guidance on the contents of a 10 CFR Part 70 license application that only authorizes possession of special nuclear material for the purpose of loading it into factory-fabricated modules is available in draft NUREG-2212, "Standard Review Plan for Applications for 10 CFR Part 70 Licenses for Possession and Use of Special Nuclear Materials of Critical Mass but Not Subject to the Requirements in 10 CFR Part 70, Subpart H – Draft Report for Comment," issued December 2022 (ML22335A087), which the NRC staff currently plans to publish as final in summer 2024 for licensees not subject to the requirements in 10 CFR Part 70, Subpart H.[15]

The 10 CFR Part 70 license would specify the quantity and form of special nuclear material allowed to be possessed and include the appropriate conditions in 10 CFR 70.32, "Conditions of licenses." The manufacturing license would include the final design information for the factory-fabricated module, including the features to preclude criticality. The manufacturing license would cover the reactor design and manufacturing process and has not traditionally been thought to include conditions related to radiological safety at the manufacturing facility itself. The 10 CFR

[15] The provisions of 10 CFR Part 70, Subpart H, "Additional Requirements for Certain Licensees Authorized To Possess a Critical Mass of Special Nuclear Material," would not be applicable to a 10 CFR Part 70 license that only authorizes possession of special nuclear material for the purpose of loading it into factory-fabricated modules because the applicability criteria in 10 CFR 70.60, "Applicability," would not be satisfied. Loading fuel into a micro-reactor under this option is not encompassed by the enumerated activities in 10 CFR 70.60 and is not an activity meeting the 10 CFR 70.60 criterion "could significantly affect public health and safety" because it lacks the significant hazards associated with the enrichment, conversion, and fabrication activities that are subject to the requirements of Subpart H, *provided that* measures to preclude criticality as described in Option 1b are correctly implemented. If the 10 CFR Part 70 license also authorizes other fuel cycle activities, such as fuel fabrication, then the regulations in 10 CFR Part 70, Subpart H and the guidance in the standard review plan, "Standard Review Plan for Fuel Cycle Facilities License Applications (NUREG-1520)" (ML15176A258), would instead be applicable.

Part 70 license would place requirements on areas, structures, and equipment within the factory where the fuel is handled and stored. Therefore, the applicant for or holder of the manufacturing license may benefit from approval of the 10 CFR Part 70 license before building a factory that would include both the manufacturing facility and areas for fuel storage and handling.

The regulations in 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," require the NRC to perform environmental reviews in connection with issuance of 10 CFR Part 52 manufacturing licenses for the design and manufacturing of reactor modules and 10 CFR Part 70 licenses for the possession and use of special nuclear material. In accordance with 10 CFR 51.30(e), the environmental assessment for a manufacturing license addresses the consideration of the costs and benefits of severe accident mitigation design alternatives and the bases for not incorporating severe accident mitigation design alternatives in the design. The environmental review for the 10 CFR Part 70 license could require an environmental assessment or EIS, depending on the environmental impact of the activities requested and authorized by the license.

The NRC staff recognizes that some micro-reactor deployment models may include either concurrent or separate requests for a 10 CFR Part 52 manufacturing license and a 10 CFR Part 70 license, which could raise unique, case-specific environmental review considerations.[16] Therefore, the NRC staff encourages prospective applicants to make the NRC staff aware of all planned activities for a factory through preapplication engagement. Such engagement will facilitate the NRC's meeting its NEPA obligations to consider and evaluate cumulative impacts and connected actions. Additional environmental reviews would be performed for each deployment site consistent with the regulations for issuance of permits and licenses under 10 CFR Part 50 or 10 CFR Part 52.

Under Option 2b, there may be inconsistent treatment in application of the financial protection requirements under 10 CFR Part 140. There are no financial protection regulations in 10 CFR Part 140 explicitly addressing fuel loading under a manufacturing license and 10 CFR Part 70 license. In the scenario where a licensee is authorized to possess fuel prior to being authorized to operate, licensees that hold a construction permit or combined license are similarly situated to licensees that hold a manufacturing license. Under 10 CFR 140.13, "Amount of financial protection required of certain holders of construction permits and combined licenses under 10 CFR Part 52," holders of construction permits before issuance of an operating license and holders of combined licenses before the Commission's 10 CFR 52.103(g) finding, who also hold a license under 10 CFR Part 70 for the fuel to be used in operation of the nuclear reactor, must have and maintain financial protection in the amount of $1 million.[17] Additional financial protection requirements are provided in 10 CFR 140.13a, "Amount of financial protection required for plutonium processing and fuel fabrication plants," and 10 CFR 140.13b, "Amount of liability insurance required for uranium enrichment facilities"; however, these requirements are

[16] There may also be case-specific environmental review considerations under Option 2a and under the options in this paper for operational testing at a factory in which the 10 CFR Part 52 manufacturing license process and the 10 CFR Part 50 or 10 CFR Part 52 processes for licensing construction and operation are used in combination.

[17] The regulations in 10 CFR 140.11, "Amounts of financial protection for certain reactors," and 10 CFR 140.12, "Amount of financial protection required for other reactors," address financial protection for reactors authorized to operate. As such, these requirements would not be applicable to factory-fabricated modules that included features to preclude criticality that would only be loaded with fuel and not operated at a manufacturing facility.

not applicable to manufacture of micro-reactors. Therefore, the NRC staff would propose to use license conditions or another appropriate regulatory vehicle to address this inconsistency during the period before issuance of the operating license or before the Commission makes the finding under 10 CFR 52.103(g).

The 10 CFR Part 53 draft proposed rule package seeks stakeholder feedback on whether to allow fuel load under a manufacturing license and a 10 CFR Part 70 license without requiring a combined license. Even if such a proposal were approved by the Commission and ultimately adopted in 10 CFR Part 53, that approach might not be available in time to support some developers' plans, especially those that have indicated that they intend to manufacture and deploy factory-fabricated modules under licenses issued pursuant to 10 CFR Part 52. The option presented in this paper would provide an approach to address fuel loading at a factory in the near term under the current regulations that would provide regulatory clarity for micro-reactor developers, before a rulemaking can be completed.

Implementation

If the Commission directs the NRC staff to pursue this option, the NRC staff would develop guidance for developing an application for a 10 CFR Part 70 license in conjunction with a manufacturing license to authorize fuel loading at the factory. The NRC staff would also consider an appropriate regulatory vehicle for ensuring adequate financial protection and establishing indemnity agreements and engage the Commission, as appropriate.

Advantages

- The requirements for 10 CFR Part 70 licenses better match the technical and safety aspects of loading fuel into a micro-reactor with features to preclude criticality than the requirements of 10 CFR Part 50 and 10 CFR Part 52 that apply to an operating utilization facility.

- The NRC staff can implement this option in the timeframes being considered by micro-reactor developers for deployment of factory-fabricated modules.

- Compared to Option 2a, this approach would reduce the number of administrative requirements for individual modules, which would likely improve the efficiency and timeliness of licensing and deployment.

Disadvantages

- The NRC staff has not used 10 CFR Part 70 licensing in conjunction with a manufacturing license for this purpose and the NRC staff would need to develop related guidance, including on features to preclude criticality that would be specified in the manufacturing license.

- Under this option, the NRC staff would have to pursue an appropriate regulatory vehicle to ensure that licensees establish and maintain adequate financial protection and indemnity agreements, including further Commission engagement, if appropriate.

Topic 3: Operational Testing at a Factory

Some factory-fabricated-micro-reactor deployment models include operational testing of factory-fabricated modules at the factory before delivery to the deployment site. Under the options described below, operational testing would involve making the reactor critical. In one scenario, the factory-fabricated module would be operated at low power levels for the purpose of physics testing. In another scenario, which would more likely apply to self-contained designs, the factory-fabricated module would be operated at full power to verify that all systems function as designed.

Operational testing at a factory would require the fabricator to obtain a facility construction permit and operating license pursuant to 10 CFR Part 50 or a combined license pursuant to 10 CFR Part 52 for each factory-fabricated module, and to comply with all relevant regulatory requirements. After completion of operational testing, the licensee would install features to preclude criticality to take the reactor out of operation in addition to ensuring that all other necessary measures are taken to protect personnel and maintain the module in a safe condition before shipment. The factory-fabricated module would be covered under the manufacturing license holder's 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," and 10 CFR Part 70 licenses authorizing the possession of the byproduct and special nuclear material contained in the module. The manufacturing license would also continue to authorize possession of the factory-fabricated module until its receipt by a licensee authorized to acquire it at the deployment site under a separate 10 CFR Part 50 or 10 CFR Part 52 license.

The options below would cover both fuel loading and operational testing at the factory.

Option 3a—Authorize operation for testing under a power reactor license

Under this option, the fabricator would need a power reactor construction permit and operating license or combined license to operate each factory-fabricated module as a commercial micro-reactor for testing at the factory. This option represents the "status quo" in that it relies on the current regulations and does not involve policy matters. The processes for obtaining the necessary licenses would be the same as those described in Option 2a, above.

Whether licensed to perform operational testing under 10 CFR Part 50 or 10 CFR Part 52, the licensee would need to address power reactor requirements for operational programs on matters such as security, emergency preparedness, fitness for duty, radiation protection, and operator training and licensing. As stated in SECY-20-0093, micro-reactors differ significantly from large light-water reactors, and operational requirements in regulations that were developed with large light-water reactor facilities in mind may be more extensive than necessary for micro-reactors to operate safely. SECY-20-0093 also states that, "[p]rovided a micro-reactor applicant can demonstrate the safety and security of its design and show the facility represents a low risk, the [NRC] staff recognizes that different licensing and regulatory approaches are appropriate for such facilities."

License conditions governing operational testing at a factory would generally further reduce the risk associated with operation of a micro-reactor by imposing limitations on the reactor's maximum power level or cumulative operating time or both. Such limitations would result in a

lower radionuclide inventory and correspondingly reduce the potential radiological hazards to the public in the unlikely event of an accident to a very small fraction of those considered for extended operation of large light-water reactors. Also, limitations on the power level and duration of operation could, for example, simplify operational programs for radiation protection during and after operation because of smaller amounts of radioactive effluents and lower radiation fields. For these reasons and others, compliance with all requirements (e.g., those related to operational programs) in 10 CFR Part 50 or 10 CFR Part 52 might not be necessary or desirable to promote the common defense and security or to protect public health and safety in view of the expected lower risk associated with operational testing at the factory.

Depending on the specifics of the operational testing program, the Commission could use regulatory vehicles including license conditions, exemptions, hearing orders, or rules of particular applicability in order to adjust the review necessary to issue a license that authorizes operational testing. However, the AEA mandates certain requirements such as hearings, ITAAC (Part 52), and ACRS review. In addition, if operational programs were appropriately adjusted for testing at a factory, those programs would likely not be adequate for full-power extended operation at deployment sites, so different or modified programs would have to be reviewed as part of the application for the facility operating license or combined license at the deployment site.

Implementation

The NRC staff would implement this option by applying the existing regulations for power reactor licensing and NRC staff guidance for risk informing reviews of applications for licenses that would authorize operational testing of factory-fabricated modules. The NRC staff may further engage the Commission, particularly if hearing orders or rules of particular applicability are used.

Advantages

- The existing requirements in 10 CFR Part 50 and 10 CFR Part 52 and associated guidance could be used to facilitate this licensing approach.

- In some cases, the review could be streamlined. Where the fabricator has a final design already approved by the NRC with maximum standardization (such as in a manufacturing license), the scope of review for licensing could be considerably narrowed. Similarly, the review process could be more efficient if the fabricator applies for a manufacturing license and a combined license together and combined licenses are issued simultaneously for each reactor to be manufactured. Also, the ITAAC closure and hearing processes for each reactor could potentially be coordinated for both the factory and deployment site if the deployment site combined license is issued before operational testing at the factory.

Disadvantages

- The regulatory burden on the manufacturer and NRC staff associated with licensing short duration operational testing under the regulations for nuclear power reactors may not be commensurate with the low risk posed by that activity.

- The NRC staff would need to appropriately adjust power reactor requirements for the review of a factory-fabricated module that would be licensed only for operational testing. Although relevant guidance exists,[18] this could require substantial NRC staff resources compared to Option 3b, below, which would apply the non-power reactor regulations to operational testing at the factory. In addition, operational programs that were adjusted for testing at a factory would likely not support licensing at the deployment site.

Option 3b—Apply the regulations for non-power reactors to authorize fuel loading and operational testing at a factory

This option would provide a second regulatory pathway for applicants under 10 CFR Part 50 by applying the safety regulations for non-power reactors to licensing of fuel loading and operational testing at a factory.[19] Under this option, the factory-fabricated modules would be manufactured in accordance with a manufacturing license issued pursuant to 10 CFR Part 52 that includes an approved nuclear power reactor design. A construction permit and operating licenses under 10 CFR Part 50 would then be needed to support fuel loading and operational testing at the factory, following a licensing process similar to the Part 50 licensing approach under Option 3a. While permits and licenses would be issued for nuclear power reactors, the NRC staff would apply the regulations for non-power reactors to the safety review of the construction permit and operating license application(s) through the use of appropriate regulatory vehicles (e.g., exemptions or a rule of particular applicability).[20] The NRC staff notes that this option and Option 3a are not mutually exclusive. If the Commission directs the NRC staff to pursue Option 3b, it would be up to the manufacturer to decide if the approach described in this option would be advantageous for its deployment model.

The operational characteristics of and safety considerations for commercial micro-reactors operated at the factory only for testing would be similar to those for most currently licensed non-power reactors. The NRC staff expects that operational testing could be done in a few days of operation or less at power levels between a few kilowatts to several tens of megawatts. Operational testing at a factory should have low potential radiological consequences because the radionuclide inventories generated during operational testing would be comparable to those for existing non-power reactors and a fraction of a percent of those generated by extended operation of large light-water reactors. Similar to currently licensed non-power reactors, the commercial micro-reactors operated for testing in a factory under this option may also have fewer and simpler systems and operating procedures, require less cooling during and after operation, rely less on active safety features, and generate very small amounts of radioactive effluents compared to large light-water reactors. For these reasons, the non-power reactor

---

18 See, for example, Office of Nuclear Reactor Regulation Office Instruction LIC-206, "Integrated Risk-Informed Decision-Making for Licensing Reviews," dated June 10, 2019 (ML19031C861).

19 This option could not be pursued under 10 CFR Part 52 because Part 52 is limited to power reactors.

20 Nonetheless, the fabrication of the reactor and other factory activities that are relied on for deployment site licensing must satisfy the pertinent power reactor requirements.

safety regulations better reflect the considerations undergirding the required findings and reasonable assurance determinations for issuing permits and licenses for fuel loading and operational testing of commercial micro-reactors at a factory as compared to the power reactor regulations.

Under Option 3b, the applicant would prepare its construction permit and operating license applications and the NRC staff would conduct its safety reviews primarily using the guidance in NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," issued February 1996 (ML042430055 and ML042430048). The NRC staff would rely on the power reactor design approved in the manufacturing license in its safety evaluations related to the construction permit(s) and operating license(s) for operational testing. The NRC staff would focus its review of the construction permit and operating license applications on siting; environmental reviews; operational programs such as technical specifications, operator licensing, and radiation protection; and any other unique considerations not covered in the approval of the power reactor design in the manufacturing license. The NRC staff would assess the appropriateness of and apply the necessary non-power reactor regulations and guidance for operational programs to account for a wide variety of designs and operational testing characteristics. Under this option, the applicant would also describe the number of commercial reactors proposed to be constructed at the factory, the number to be operated simultaneously, and the total number of fueled reactors proposed to be located at the site at one time. The NRC staff would need this information to appropriately consider the cumulative risk associated with the activities at the factory that are described in the construction permit and operating license applications. This information would also be necessary for the NRC staff to make other determinations, such as performing the appropriate environmental review and evaluating the amount of financial protection required by 10 CFR 140.11 and 10 CFR 140.12.

Option 3b would require the Commission to agree as a matter of policy that a factory-fabricated module could be licensed for operational testing at the factory using the safety regulations for non-power reactors even though the micro-reactors would have been manufactured and licensed as power reactors at the factory and would ultimately be operated as power reactors at the deployment sites. The NRC staff's practice has been to apply power reactor regulations throughout the lifecycle of a power reactor, and this option would be a departure from that practice. This option would also require an appropriate regulatory vehicle (e.g., exemptions or a rule of particular applicability) for the factory site micro-reactor applicant to be subject to the non-power reactor regulations rather than those for power reactors. In addition, licensing operational testing at a factory by applying the non-power reactor regulations would limit the ability to combine licensing proceedings at the factory with licensing proceedings at deployment sites because different regulatory requirements would apply to each proceeding.

The NRC's regulations for power reactors appear in different parts of 10 CFR Chapter I, and exemption requests to apply non-power reactor safety requirements would need to address the pertinent exemption criteria for the regulations in each part. For example, exemptions from regulations in 10 CFR Part 50 must satisfy 10 CFR 50.12, "Specific exemptions," which, among other things, requires that exemptions be authorized by law, not present an undue risk to the public health and safety, and be consistent with the common defense and security. The NRC staff notes that such exemptions are consistent with AEA section 103, which provides for licensing commercial utilization facilities whether or not they are power reactors. Further, as

discussed above, the factory site micro-reactor applicant would likely be able to show that appropriate application of the non-power reactor safety regulations to operational testing at the factory would not present an undue risk to the public health and safety and would be consistent with the common defense and security. The NRC staff expects applicants to be able to make these showings because the operational and safety characteristics of commercial micro-reactors when operated for testing at a factory will be similar to those of non-power reactors currently licensed for operation.

The regulations in 10 CFR 50.12 also specify that the Commission will not consider granting an exemption unless special circumstances are present. For operational testing of micro-reactors at the factory, the applicant may be able to show that special circumstances are present such as those described in 10 CFR 50.12(a)(2)(ii), which states, "[a]pplication of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule." As discussed in this option, application of the 10 CFR Part 50 power reactor regulations may not be necessary to achieve the underlying purpose of those rules if the applicant can demonstrate that the non-power reactor regulations are adequate to accomplish their purposes. In any case, the commercial micro-reactor applicant would be responsible for demonstrating that special circumstances exist, as specified in 10 CFR 50.12(a)(2), in its justification for a request for an exemption from the power reactor regulations to apply non-power reactor safety requirements.

For construction permit and full-power operating license applications for power reactors and testing facilities, 10 CFR 51.20(b) requires an EIS or a supplement to an EIS, but an EIS is not automatically required for a construction permit or operating license application for non-power reactors other than testing facilities. An exemption from the EIS requirements for power reactors in 10 CFR Part 51 might be appropriate for applications to operate micro-reactors at the factory only for testing. Any such exemptions must satisfy 10 CFR 51.6, "Specific exemptions." Because EISs are required for testing facilities, the NRC staff would, in deciding whether to grant such exemptions, consider whether the technical characteristics of the commercial micro-reactor when operated for testing at a factory might otherwise fall within the definition of "testing facility" in 10 CFR 50.2, as well as the number of reactors to be constructed and operated at the factory and the proposed scope of operational testing. If the NRC staff determines that an exemption from the requirements for an EIS is warranted, the NRC staff would prepare an environmental assessment. If the NRC staff makes a finding of no significant impact after preparing the environmental assessment, then an EIS would not be required.

Implementation

If the Commission directs the NRC staff to pursue this option, the NRC staff would use license conditions, exemptions, hearing orders, rules of particular applicability, or other regulatory vehicles, as appropriate, to implement the option. Also, the NRC staff would implement the option in a manner that avoids potential regulatory gaps. The NRC staff would consider developing additional guidance, as necessary, related to applying non-power reactor regulations to the preparation and review of construction permit and operating license applications for

operational testing of commercial micro-reactors at a factory, including those micro-reactors that reference a power reactor design approved in a manufacturing license.

Advantages

- This option would eliminate the need to tailor the power reactor regulations on a case-by-case basis for authorizing operational testing at a factory because the regulations for non-power reactors are well-established, largely performance-based, and are generally adequate for authorizing operational testing of commercial micro-reactors at a factory. The NRC has experience applying non-power reactor regulations and guidance to the review and authorization of reactor operation at thermal power levels ranging from a few watts to several tens of megawatts.

- Compared to Option 3a, the programs required for operational testing under this option could be more commensurate with the risks associated with the limited scope and duration of operational testing envisioned by factory-fabricated micro-reactor developers and reduce the associated regulatory burden while maintaining adequate protection of public health and safety.

- The environmental review would also be simplified compared to Option 3a if licensing of the commercial micro-reactors for operational testing at a factory could be appropriately covered by an environmental assessment rather than an EIS.

- Additionally, operator licensing may be less burdensome compared to Option 3a, as this option could utilize the non-power reactor operator licensing process in lieu of the process used at power reactor facilities.

Disadvantages

- It may not be possible to combine the proceedings for issuing the facility operating licenses at the factory with the proceedings associated with power reactor licenses at the deployment sites (as would be the case under Option 3a) because the commercial micro-reactors would be licensed for operational testing at the factory under the regulations for non-power reactors.

- In addition, this option may be less advantageous for operational testing of factory-fabricated micro-reactors that would have similar characteristics to a “testing facility,” as defined in 10 CFR 50.2 (e.g., thermal power level in excess of 10 megawatts or thermal power level in excess of 1 megawatt for reactors with a liquid fuel loading), because the regulations applicable to testing facilities include certain regulations applicable to power reactors, such as some of the siting criteria in 10 CFR Part 100 and the requirement for an EIS under 10 CFR Part 51.

Enclosure:
Technical, Licensing, and Policy Considerations
for Factory-Fabricated Micro-Reactors