Technology-neutral licensing of advanced reactors: Evaluating the past and present NRC framework

*by Maxine Segarnick and Sachin Desai**

I. Summary

Advanced reactors[1] have promise as the future of United States nuclear energy infrastructure. However, licensing these reactors presents many new questions for the nuclear community, particularly around developing a "technology-neutral" framework capable of handling a staggering amount of diversity in technologies and operating models. Congress's enactment of the Nuclear Energy Innovation and Modernization Act (NEIMA) in early 2019 enables the United States Nuclear Regulatory Commission (NRC) to devote substantial resources to developing such a framework. Congress draws a distinction between the existing licensing framework that is focused on light water reactors (LWRs) and the technology-neutral framework that it directs the NRC to establish.

However, to aid in the eventual development of a "technology-neutral" reactor licensing framework, it is important to conceptually understand the history and context of the current licensing framework for commercial nuclear power plants (NPPs). To that end, this study analyses whether the existing licensing framework was ever intended to be fully applicable to advanced reactors.

The study reveals that, while the existing framework did not ignore advanced reactors and is capable of accomplishing the review and licensing of such reactors, the current NRC regulatory framework ultimately was designed primarily for licensing traditional LWRs. This conclusion is reached through a review of regulatory history documents and policy statements of the time and illustrates how the existing framework was not specifically intended to provide a technology-neutral framework. Thus, significant gains may be possible by learning from past experience when exploring a new licensing framework that more substantially addresses technology-neutral licensing concepts.

* Maxine Segarnick is an attorney in the Office of the General Counsel at the US Nuclear Regulatory Commission. Sachin Desai is a Senior Associate at the law firm of Hogan Lovells US LLP. The views expressed herein are those of the authors alone, and do not necessarily represent the views of the US Nuclear Regulatory Commission, the law firm Hogan Lovells US LLP, or any other person or organisation.

1. This study adopts the definition of advanced reactors in Section 3 of the Nuclear Energy Innovation and Modernization Act (NEIMA), Pub. L. 115-439, 132 Stat. 5565 (14 Jan. 2019). NEIMA broadly defines advanced reactors to include reactors "with significant improvements compared to commercial nuclear reactors under construction as of the date of enactment of this Act", including with regard to safety, cost, waste, proliferation and other factors. This definition covers next-generation LWRs as well as fusion systems. Other definitions of advanced reactors include the definition of "Generation IV" reactors, which the Generation IV International Forum (GIF) describes as designs that will "use fuel more efficiently, reduce waste production, be economically competitive, and meet stringent standards of safety and proliferation resistance." GIF, "Generation IV Systems", www.gen-4.org/gif/jcms/c_59461/generation-iv-systems (accessed 25 Nov. 2019).

II. Differences in licensing advanced reactors versus LWRs

Advanced reactors may revolutionise the supply of energy generation in the United States and potentially the world – but, to realise this potential, the NPP licensing framework must address the fundamental technical differences between the operating fleet of large LWRs and advanced reactor designs.

The current commercial nuclear power plant infrastructure in the United States is made up entirely of large LWRs, named as such because they use "light water" (i.e. water that is primarily comprised of protium hydrogen) as the moderator and working fluid. There are two main types of LWRs: pressurised water reactors (PWRs) and boiling water reactors (BWRs). The operating fleet of LWRs in the United States consists of 96 licensed reactors (64 PWRs and 32 BWRs) ranging in thermal output from about 1 600 to 4 500 megawatts thermal (MWt) (thus the inclusion of "large" in the name "large light water reactors").[2]

In contrast to large LWRs that comprise the current US reactor fleet, advanced reactor technologies hold promise to be smaller, simpler and even safer. Advanced reactors are considered safer in large part because of their passive or inherent safety features, which rely on gravity, convection or heat capacity rather than active operational controls in the event of an accident or malfunction. Some of the main differences between large LWRs and advanced reactors are recognised in the NRC's policy statement on advanced reactors, which states that attributes of advanced designs should include:

- "Highly reliable and less complex shutdown and decay heat removal systems", including "inherent or passive" systems;
- "Longer time constants and sufficient instrumentation to allow for more diagnosis and management before reaching safety systems challenge and/or exposure of vital equipment to adverse conditions"; and
- "Simplified safety systems that, where possible, reduce required operator actions".[3]

The result, however, is that advanced reactors present many fundamentally new design features compared to the current LWR fleet, which further present questions of first impression as to safety and licensing. For example, some advanced reactor designs employ and rely on passive safety features like natural circulation and convection, as opposed to actively-managed emergency-core cooling systems that LWRs currently use.[4] Certain passive safety features are also being proposed that would allow reactors to operate at atmospheric pressure, and could reduce or

2. NRC (updated 26 Sept. 2019), "Power Reactors", www.nrc.gov/reactors/power.html (accessed 25 November 2019); NRC (2019), *Information Digest, 2019-2020*, NUREG-1350, Vol. 31, NRC, Washington, DC, Appendix A, "Commercial Nuclear Power Reactors Operating Reactors", Agencywide Documents Access and Management System (ADAMS) Accession No. ML19242D336. Documents referenced in this article with an "ADAMS" number can be retrieved by a search on NRC's Agencywide Documents Access and Management System website at: www.nrc.gov/reading-rm/adams.html#web-based-adams.
3. Policy Statement on the Regulation of Advanced Reactors, 73 Federal Register (Fed. Reg.) 60612 (14 Oct. 2008).
4. See e.g. *Advances in Small Modular Reactor Technology Developments* (Supplement to International Atomic Energy Agency Advanced Reactors Information System) (2016 ed.), IAEA, Vienna, pp. 124, 327, available at: https://aris.iaea.org/Publications/SMR-Book_2016.pdf (describing the convection-based cooling systems of the NuScale Power Module, and a cooling system for the Terrestrial Energy Integral Molten Salt Reactor that relies on heat capacity, thermal radiation and air cooling).

eliminate the need for substantial offsite emergency planning. While such designs may eliminate the risk of a Fukushima-type accident if active cooling systems fail,[5] they represent significant departures from past practice.

Further, as opposed to traditional large-scale plants, advanced reactors may be designed to be "modular", averaging around 50-100 megawatts electrical (MWe) per reactor, meaning that the reactors may be built at factories and shipped to operating sites. This potentially significant opportunity for cost-savings also presents new questions as to licensing of reactors manufactured off-site, which are then transported and installed as complete units where they will be operated. For example, when does NRC direct oversight over construction of nuclear power plants begin for plants built in decentralised construction facilities and later assembled at a plant "site"?

Finally, many advanced reactor designs will use new types of nuclear fuel – including liquid, gaseous and solid fuels. Molten salt reactors, for example, use a liquid fuel that can harden into a solid in case of a reactor coolant failure, thereby trapping the nuclear materials.[6] Some advanced reactor designs also plan to use "fast" neutrons to burn the un-enriched or so-called "depleted" uranium in a fuel rod. This approach reduces the amount of leftover fuel that could become a proliferation or waste concern,[7] but at the same time raises new questions about licensing a type of reactor with different reactor physics and fuel management strategies.[8]

Diversity is also an important characteristic of the advanced reactor movement. Never before have so many fundamentally different ways been proposed to design, build and operate a nuclear power reactor. There are dozens of companies[9] participating in the emerging field of advanced reactors in the United States alone, with many more participating around the world. Regulators need to be prepared to efficiently licence a variety of designs that differ in basic characteristics, such as the fuel, working fluid, reactor shape and neutron spectrum.

Such diversity is likely to push the current regulatory framework in ways that have not been explored in the past. In response to this concern, on 14 January 2019, Congress passed the Nuclear Energy Innovation and Modernization Act (NEIMA), which, in part, requires the NRC to establish by the end of 2027 a technology-inclusive regulatory framework for advanced reactors that accommodates greater technological innovation. While the idea of promulgating risk-informed, technology-neutral, performance-based regulations for reactor licensing has been discussed for over a

5. Martin, R. (Sept. 2015), "Meltdown-Proof Nuclear Reactors Get a Safety Check in Europe", *MIT Technology Review*, Massachusetts Institute of Technology, Boston, p. 4.
6. See e.g. Terrestrial Energy website, www.terrestrialenergy.com (accessed 25 Nov. 2019).
7. See e.g. TerraPower (29 Oct. 2015), "A Solution to the Nuclear Waste Problem", https://terrapower.com/updates/a-solution-to-the-nuclear-waste-problem (accessed 25 Nov. 2019).
8. World Nuclear Association (Sept. 2019), "Fast Neutron Reactors", www.world-nuclear.org/information-library/current-and-future-generation/fast-neutron-reactors.aspx ("Due to the high radiation levels in the core, using simply a core and no blanket gives rise to some new challenges in how the fuel is fabricated and managed.") (accessed 25 Nov. 2019).
9. Allen T., R. Fitzpatrick, and J. Milko (12 Dec. 2016), "The Advanced Nuclear Industry: 2016 Update", Third Way, https://thirdway.imgix.net/downloads/the-advanced-nuclear-industry-2016-update/the-advanced-nuclear-industry-2016-update_032717.pdf (accessed 25 Nov. 2019).

decade,[10] NEIMA presents a new opportunity due to its rulemaking mandate to the agency and accompanying authorisation for funding to be appropriated for the fiscal years 2020 through 2024.[11]

To more fully understand how the current framework would respond to a wave of advanced reactor licence applications, particularly before making modifications to the framework that may be called for under NEIMA, it is important to first understand the historical context of the development of the current reactor licensing framework. Only by knowing where we have come from can we more fully understand how to move forward.

III. NRC licensing: Past and present

A. Where we have come from: A focus on LWRs in licensing

The structure of reactor licensing in the United States has evolved over time from a two-step framework (i.e. the licensing approach in Part 50 of the *Code of Federal Regulations* [10 CFR], as originally promulgated) to an approval process that has encouraged design standardisation and favoured a more predictable "one-step" licensing process. These themes are seen in the development of the general design criteria in 10 CFR Part 50 Appendix A in the 1970s (which focus on LWRs) and more recently in the creation of the 10 CFR Part 52 licensing process.[12]

The applicability of these frameworks to licensing advanced reactors is threaded throughout the underlying regulatory history and policy. However, reviewing the history closely, it becomes apparent that, while passively safe and non-LWR reactor concepts were on the minds of regulators since the dawn of the nuclear era, the regulatory framework was not intended to directly address the design features that embody the advanced reactor designs being introduced today. This article will dive into the underlying history to parse out the intentions for licensing advanced reactors under Parts 50 and 52 to shed light on how the NRC arrived at what may ultimately become "Part 53."

1. The early NRC regulatory framework increasingly focused on LWR licensing

The NRC's original two-step licensing process in 10 CFR Part 50 was applied to all designs put before the Atomic Energy Commission (AEC), the NRC's predecessor agency in licensing the first reactors in the 1950s and 1960s. Some of the first nuclear power plants that the NRC licensed included a 50 MWt BWR licensed in 1957 (General Electric's VBWR, "Vallecitos", shut down in 1963), a 23.5 MWt PWR licensed in 1961

10. See e.g. Memorandum for the Commissioners from L. Reyes, Executive Director for Operations (EDO), NRC (9 Jan. 2006), "Staff Plan To Make a Risk-Informed and Performance-based Revision to 10 CFR Part 50", SECY-06-007 (ADAMS Accession No. ML053420151) ("The staff proposes to achieve the Commission's direction to make a risk-informed and performance-based revision to 10 CFR Part 50 by creating a completely new risk-informed and performance-based Part 50 (to be called Part 53) that is applicable to all reactor technologies. The development of this new Part 53 will integrate safety, security, and preparedness."). Subsequently, the Commission approved NRC staff's recommendation to defer a rulemaking to make 10 CFR Part 50 risk-informed and performance-based. Memorandum to L. Reyes, EDO, from A. Vietti-Cook, Secretary (14 June 2007), "Staff Requirements – SECY-07-0101 Staff Recommendations Regarding a Risk-Informed and Performance-Based Revision to 10 CFR Part 50 (RIN 3150-AH81)" (ADAMS Accession No. ML070790236).
11. NEIMA, sec. 103(a)(6) ("There is authorized to be appropriated to the Commission to carry out this subsection $14,420,000 for each of fiscal years 2020 through 2024.").
12. An in-depth explanation of the structure of licensing under Parts 50 and 52 can be found in Burns, S. (2017), "Reformed and Reforming: Adapting the Licensing Process to Meet New Challenges", *Nuclear Law Bulletin,* No. 99, OECD, Paris, pp. 9-18.

("Saxton", shut down in 1972), and a 600 MWt PWR licensed in 1963 ("Yankee Rowe", shut down in 1992); but also several non-LWR designs, such as a 200 MWt sodium-cooled fast reactor licensed in 1963 ("Fermi 1", shut down in 1972),[13] and a 330-MWe high-temperature gas-cooled reactor (HTGR) that utilised a uranium-thorium fuel cycle ("Fort Saint Vrain", licensed in 1979 and shut down in 1989).[14] However, the vast majority of reactors built during this period were LWRs,[15] with the result being that the licensing standards, and their application within the broader licensing framework, naturally followed suit.

The reasons for the shift towards LWRs in the United States are well-known. One key factor was the military's use of LWRs in naval ships and submarines, and the natural diffusion of this technology into the commercial power sector. The first civilian nuclear reactor ever built was assembled in Shippingport, Pennsylvania, from a military LWR that was converted with help from none other than Admiral Hyman G. Rickover's team (Admiral Rickover was the founder of the US nuclear navy).[16] A second driver was the US government's early push to scale up the nuclear industry at a rapid pace, which cemented around the already-successful LWRs. As stated in a Brookings Institution publication: "[T]he Atomic Energy Commission endorsed a cookie-cutter-like approach to building additional reactors that was very enticing to energy companies seeking to enter the atomic arena. Having a standardised light water reactor design meant quicker regulatory approval, economies of scale, and operating uniformity, which helped control costs and minimise uncertainty."[17]

2. *Licensing reform focused on licensing standards for LWRs over development of a technology-neutral regulatory framework*

In the 1970s, discussion emerged regarding a new generation of reactor designs, which appeared to share similar attributes to modern-day advanced reactors – including a focus on improved safety systems. In 1974, Congress established the NRC from the former AEC,[18] and in doing so, guided the NRC's policy with respect to regulation of advanced reactors. As the NRC explained in its 1985 proposed policy on advanced reactors, Congress instructed the NRC under the amended Section 205 of the Energy Reorganization Act, to provide a "long-term plan for projects for the development of new or improved safety systems for nuclear power plants."[19] The proposed policy listed the NRC's past experience in the regulation of advanced reactors in the 1970s,

13. *NRC Information Digest 2019-2020*, *supra* note 2, Appendix C, "Commercial Nuclear Power Reactors Undergoing Decommissioning and Permanently Shut Down Formerly Licensed to Operate", pp. 116-119.
14. NRC, Office of Nuclear Regulatory Research (Jan. 2004), *Fort Saint Vrain Gas Cooled Reactor Operational Experience*, NUREG/CR-6839, p. 3.
15. In the two decades of the 1960s and the 1970s, apart from licensing of a few non-LWRs such as Fermi 1 and Fort Saint Vrain, over fifty LWRs started commercial operation. See US Energy Information Administration (Feb. 2016), *Nuclear and Uranium*, "Spent Nuclear Fuel", Table 2, "Nuclear power plant data as of June 30, 2013", www.eia.gov/nuclear/spent_fuel/ussnftab2.php (accessed 25 Nov. 2019).
16. Shik Jr., W.L. (2009), "Atoms for Peace in Pennsylvania", *Pennsylvania Heritage Magazine*, Pennsylvania Heritage Foundation, Harrisburg, PA, Vol. 35, No. 2, available at: www.phmc.state.pa.us/portal/communities/pa-heritage/atoms-for-peace-pennsylvania.html (accessed 25 Nov. 2019).
17. Freed, J. (12 Dec. 2014), "Back to the Future: Advanced Nuclear Energy and the Battle Against Climate Change", Brookings Institution, Washington, DC, http://csweb.brookings.edu/content/research/essays/2014/backtothefuture.html (accessed 25 Nov. 2019).
18. Energy Reorganization Act of 1974, Pub. L. 93-438, 88 Stat. 1233 (11 Oct. 1974), codified at 42 United States Code (USC) 5801 *et seq*.
19. 42 USC 5845(f), as amended by Pub. L. 95-209, sec. 4(a), 91 Stat. 1481, 1482 (13 Dec. 1977); see Proposed Policy for the Regulation of Advanced Nuclear Power Plants, 50 Fed. Reg. 11882 (26 Mar. 1985).

including the NRC's review of HTGRs, liquid metal fast breeder reactors (LMFBRs) and a conceptual design for a gas-cooled breeder reactor.[20]

To this end, in 1986 the NRC adopted its final policy statement on the review of, and desired characteristics associated with, advanced rectors.[21] In this statement, the Commission appeared to agree that changes needed to be made to the 10 CFR Part 50 framework to accommodate the potential new licensing wave of non-LWR reactor designs. In its policy statement, for example, the NRC explained that "the Commission intends to develop the capability for timely assessment and response to innovative and advanced designs that might be presented for NRC review."[22] The NRC also stated that new reactor designs "may involve technical problems that must be solved in order to assure adequate protection of the public health and safety", and that it would create a group to "coordinate the development of regulatory criteria and guidance for proposed advanced reactors."[23]

However, this recognition of a need for a technology-neutral framework for advanced reactors did not necessarily lead to a regulatory framework that focused on technology-neutral licensing. Instead, based on industry input, in 1987 the NRC issued a policy statement on the standardisation of reactor designs, which was a precursor to the 1989 promulgation of the combined licensing and design certification approach in Part 52.[24] This shift evidenced that one-of-a-kind licensing was perceived negatively: "Experience has shown that 'one-of-a-kind' approach to reactor design has led to an operating reactor population of great variability and diversity, even among reactors from the same vendor."[25] After remarking on the challenges this variability created, the Commission explained that "standardization of nuclear power plant designs can significantly enhance the safety, reliability and availability of nuclear plants."[26] This policy statement did touch on advanced reactors, noting that the desirable safety characteristics listed in the 1986 Advanced Reactor Policy Statement "are equally as desirable for evolutionary light water reactor standardized designs". However, the NRC's focus was ultimately placed on standardisation of LWRs, reflecting the apparent industry focus on LWRs and the fact that advanced reactor development was still in a nascent stage.[27]

This signals that the NRC drew ideas from advanced reactor safety characteristics (such as those found in HTGRs and LMFBRs.), but drew a distinction between those designs and the "evolutionary light water reactors" that were the apparent primary

20. Proposed Policy for the Regulation of Advanced Nuclear Power Plants, *supra* note 19, p. 11883.
21. Regulation of Advanced Nuclear Power Plants; Statement of Policy, 51 Fed. Reg. 24643 (8 July 1986).
22. *Ibid.*, p. 24645.
23. Nuclear Power Plant Standardization, Policy Statement, 52 Fed. Reg. 34884 (15 Sept. 1987).
24. *Ibid.*, p. 34884. As background, under the Part 52 process, reactor designers could apply for a design certification that other applicants could later use in their own licensing applications to construct and operate a plant, thus encouraging greater standardisation of reactor designs, and applicants could then also apply for a combined construction and operation licence rather than apply for these in stages. NRC, "Backgrounder on Nuclear Power Plant Licensing Process, Combined License (10 CFR Part 52)", www.nrc.gov/reading-rm/doc-collections/fact-sheets/licensing-process-fs.html#license (accessed 25 Nov. 2019).
25. Nuclear Power Plant Standardization, *supra* note 23, p. 34884.
26. *Ibid.*
27. NRC explained "evolutionary light-water designs" to mean "improved versions of the light-water designs now in operation", and "advanced designs" to mean "designs which differ significantly from the evolutionary light-water designs, or which incorporate, to a greater extent than evolutionary light-water designs do, simplified, inherent, passive, or other innovative means to accomplish their safety functions." Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Reactors, Final Rule, 10 CFR Part 52, 54 Fed. Reg. 15372, 15374 (18 Apr. 1989) (hereinafter Part 52 Final Rule).

focus of the design standardisation effort. The 1987 standardisation policy statement underscores its focus on LWRs by stating that "the reference system designs, at least initially, are expected to be evolutions of existing proven LWR designs …" and "[w]hen an advanced design concept is sufficiently mature, … an application for design certification could be made."[28]

There is further evidence of the acknowledgement – yet lack of direct consideration – of advanced reactor designs in the development of the 10 CFR Part 52 licensing framework in 1988 and 1989, which superseded the 1987 Policy Statement on Nuclear Power Plant Standardization.[29] The 1988 proposed rule for Part 52 responded to the public comments on this 1987 standardisation policy statement, including by providing for certification of advanced designs in the proposed rule. The 1988 proposed rule noted that: "[t]he NRC staff is currently developing safety criteria for application in the review of advanced reactor designs. These criteria will define minimum safety requirements for advanced reactors and will provide for assessment and documentation of the enhanced safety the Commission expects these reactor designs to embody."[30]

In contrast, the 1989 final rule provided for certification of advanced designs, but permitted certification of designs of less than full scope and only in highly restricted circumstances.[31] The NRC instead highlighted its focus on LWR designs: "The Commission's legislative proposals on standardization have always focused on [evolutionary LWR] designs, on the grounds that the light-water designs now in operation provide a high degree of protection to public health and safety."[32] The Commission made this point in the context of describing why prototype testing of advanced designs is required for certification or unconditional final advanced design approval.[33]

The Commission noted that "standardization along these lines may indeed limit some market forces, particularly those which encourage a *highly differentiated range of products*."[34] Later, it added, "there are also uncertainties concerning the costs of the certification process, and the costs of developing the designs themselves, especially the advanced designs, which may require testing of prototypes."[35] Thus, while advanced design applicants could use 10 CFR Part 52 to certify an advanced reactor design, the NRC acknowledged that the design standardisation approach and associated prototype testing might not be economically feasible for advanced reactor designs.[36]

In sum, while the past rulemaking efforts for NPP licensing considered advanced reactors, and the current framework is capable of licensing such reactors, the

28. Nuclear Power Plant Standardization, *supra* note 23, 52 Fed. Reg. at 34885.
29. Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Reactors, Proposed Rule, 10 CFR Part 52, 53 Fed. Reg. 32060, 32061 (23 Aug. 1988).
30. *Ibid*., p. 32063.
31. Part 52 Final Rule, *supra* note 27, 54 Fed. Reg. at 15374.
32. *Ibid*. Note that the final rule draws a distinction between "evolutionary light-water reactors" and "advanced reactors", explaining, "evolutionary light-water designs, that is, improved versions of the light-water designs now in operation, and of 'advanced' designs, that is, designs which differ significantly from the evolutionary light-water designs, or which incorporate, to a greater extent than evolutionary light-water designs do, simplified, inherent, passive, or other innovative means to accomplish their safety functions." *Ibid*.
33. *Ibid*.
34. *Ibid*., p. 15375 (emphasis added).
35. *Ibid*., p. 15385.
36. NRC's licensing regulations contain provisions for additional testing or analysis of "nuclear reactor designs which differ *significantly*" from light-water reactor designs, including provisions for use of a prototype plant for testing, thus demonstrating the NRC's consideration of, but not necessarily additional flexibility for, the licensing of advanced nuclear reactors. See 10 CFR 50.43(e) (emphasis added); see also 10 CFR 52.47(c)(2).

designers of the framework did not specifically aim to create a technology-neutral model that embraced a diversity of advanced reactor designs. The 10 CFR Part 50 standards – i.e. the technical acceptance criteria – crystalised around LWRs, and, albeit after a brief period when advanced reactor licensing was considered at a high-level, the development of 10 CFR Part 52 instead focused on standardisation with the overall goal of streamlining licensing of evolutionary LWRs. While standardisation would assist certain aspects of the review of advanced reactor designs, an explicit focus on the unique needs of advanced reactors, and particularly for a technology-neutral framework, was not at the fore.

B. Where we are now: Working within the existing framework

Today, advanced reactor licensing has returned to the fore, and the NRC has undertaken numerous efforts to prepare for advanced reactor licensing. Given the current LWR-focused regulatory framework, proposals have largely considered "licensing through exemption"[37] approaches and piece-by-piece efforts to develop licensing options for advanced reactors within the existing regulatory framework.[38] But NEIMA requires the NRC to go further and "complete a rulemaking to establish a technology-inclusive, regulatory framework for optional use by commercial advanced nuclear reactor applicants for new reactor license applications" by 31 December 2027.[39] In addition, NEIMA requires, among other things, the NRC to "develop and implement, *within the existing regulatory framework*, strategies for … establishing stages in the licensing process for commercial advanced nuclear reactors",[40] and "strategies for the increased use of risk-informed, performance-based licensing evaluation techniques and guidance for commercial advanced nuclear reactors *within the existing regulatory framework*."[41] The NRC's efforts to carry out the provisions of NEIMA within the existing regulatory framework and through rulemaking are articulated in the NRC's July 2019 report to Congress.[42] Some of these efforts are highlighted below.

Much of the NRC's advanced reactor work is outlined in the key guidance document, *NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness* (Vision and Strategy Statement).[43] In addition, the Non-LWR Vision and Strategy and Implementation Action Plans set forth two phases for advanced reactor licensing preparedness: first, conceptual planning, which the NRC completed in December 2016, and second, detailed work planning efforts and task execution, which are ongoing.[44] As part of these steps, in December 2017, the NRC published its "Regulatory Review Roadmap for Non-Light Water Reactors" (Regulatory

37. See Memorandum for the Commissioners from V. McCree, EDO (23 May 2018), "Achieving Modern Risk-Informed Regulation", SECY-18-0060, Enclosure 5, "Additional Detail on Areas of Transformation", p. 11 (ADAMS Accession No. ML18110A186) (discussing how a technology neutral framework could, "by allowing for greater regulatory flexibility, reduce or eliminate the need for exemptions from regulations under Parts 10 CFR 50 or 10 CFR 52").
38. See Memorandum for the Commissioners from V. McCree, EDO (31 Oct. 2018), "Proposed Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies", SECY-18-0103 (ADAMS Accession No. ML18134A086).
39. NEIMA, Pub. L. 115-439, sec. 103(a)(4).
40. *Ibid*., sec. 103(a)(1) (emphasis added).
41. *Ibid*., sec. 103(a)(2) (emphasis added).
42. Letter to the Honorable J. Barrasso from NRC Chairman K. Svinicki (12 July 2019) (ADAMS Accession No. ML19128A289).
43. NRC (Dec. 2016), *NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness* (ADAMS Accession No. ML16356A670).
44. NRC (July 2017), "Non-LWR Near-Term Implementation Action Plans" (ADAMS Accession No. ML17165A069); NRC (July 2017), "Non-LWR Mid-Term and Long-Term Implementation Action Plans" (ADAMS Accession No. ML17164A173).

Review Roadmap).[45] This work is consistent with NEIMA's requirement to evaluate options for licensing commercial advanced nuclear reactors under the current regulatory framework, while considering the use of new tools such as licensing project plans.[46]

The Regulatory Review Roadmap provides advanced reactor designers with an overview of the various pathways for the NRC's review of new advanced reactor designs, in order to help the designer select the best option for the design. This document is part of the NRC's "near-term implementation action plan", the development and execution of which constitute Phase 2 of the NRC's vision and strategy for achieving non-LWR readiness. Progress on the implementation of these plans is reported to the Commission annually. For example, in 2019, the NRC staff issued a status update to the Commission on the NRC staff's activities related to advanced reactors, including the progress and path forward on each of the implementation action plan strategies.[47]

In addition, the NRC engaged with industry in the development of the Licensing Modernization Project (LMP), which serves to "develop technology-inclusive, risk-informed, and performance based regulatory guidance for licensing non-LWRs for the NRC's consideration and possible endorsement."[48] The NRC has stated that it plans to issue this guidance in final form in late 2019.[49] Also, in September 2019, the NRC staff completed a draft document called the "Non-Light-Water Reactor Review Strategy – Staff White Paper".[50] This draft white paper would serve to "support the reviews of applications for non-LWR designs submitted prior to the development of the technology-inclusive, risk-informed, and performance-based regulatory framework in 2027" required by NEIMA.[51]

While these existing advanced reactor licensing preparedness efforts are undoubtedly helpful, the NRC's advanced reactor regulatory reform efforts are bounded by existing regulations and require the use of exemptions from existing requirements to address licensing of specific advanced reactor designs. And as described in the previous sections, while the existing framework is usable by advanced reactors, it is not specifically tailored to the diversity of the technical characteristics of advanced reactors.

V. Conclusion

The diversity of advanced reactors calls for a truly technology-neutral framework. The questions regarding efficiency of licensing of advanced reactors within the current NRC framework do not reflect any failure of the current NRC regulatory regime or its implementation, but instead, once the appropriate historical context within which the framework was developed is understood, reflect that the current regime prioritises LWR licensing.

45. NRC, Office of New Reactors (Dec. 2017), "A Regulatory Review Roadmap for Non-Light Water Reactors" (ADAMS Accession No. ML17312B567).
46. NEIMA, sec. 103(a).
47. Memorandum for the Commissioners from F. Brown, Director, Office of New Reactors (4 Feb. 2019), "Advanced Reactor Program Status", SECY-19-0009 (ADAMS Accession No. ML18346A075).
48. NRC, "Advanced Reactors (Non-LWR designs)" (updated 31 Oct. 2019), www.nrc.gov/reactors/new-reactors/advanced.html (accessed 25 Nov. 2019).
49. *Ibid.*
50. Memorandum from S. Lynch, Acting Chief, Advanced Reactor Licensing Branch, Division of Advanced Reactors, Office of New Reactors, to J. Monninger, Director, Division of Advanced Reactors, Office of New Reactors (30 Sept. 2019) (ADAMS Accession No. ML19275E992).
51. *Ibid.*

With Congress's enactment of NEIMA, the NRC is no longer constrained from devoting substantial resources to the development of new or revised regulatory approaches. NEIMA recognises that a key aspect of any framework must be that it is technology-neutral and adaptive to new questions that will arise as part of the licensing process. The authors hope that this article helps to provide historical context for the development of the current NRC licensing framework, to aid in the understanding and development of a technology-neutral licensing framework in the future.