Nuclear Power's Role in Meeting Energy Demand While Combating Global Warming and Climate Change

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ABSTRACT: The United States currently faces a perplexing policy challenge. Our energy infrastructure must meet the ever-increasing demand for energy to power our cities, industry, transportation, data centers, and the artificial intelligence revolution. At the same time, climate change requires that we find clean energy sources to replace fossil fuels, reduce emissions of greenhouse gases, and combat global warming. Many energy experts and environmentalists maintain that nuclear energy can meet this dual challenge in a safe, economical, and environmentally sound manner.

This Article explores the Nuclear Regulatory Commission's ("NRC") regulation of the nuclear power industry in the United States and the industry's safety record to determine if nuclear power can lead the effort to meet energy demand while combating global warming. To assess nuclear power's ability to meet this dual challenge, several questions must be answered, all of which this Article explores. Have nuclear technologies and NRC's regulation of environmental, health, and safety improved sufficiently for nuclear operations to be deemed safe? Since the Three Mile Island accident, perceived risk and fear of a nuclear disaster have overshadowed the actual risk and halted nuclear energy progress. Can advanced nuclear technologies and bipartisan support for a nuclear power overcome obstacles to progress? Are there sufficient enforceable statutory and regulatory requirements to ensure that nuclear operations remain safe? Can nuclear accidents that have occurred in the past be avoided in the future? This Article answers all these questions in the

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affirmative and then addresses a legitimate concern with nuclear power: how to deal with the storage and ultimate disposal of nuclear waste. Legal and political disputes prevented the siting and operation of the first permanent geological repository for spent fuel at Yucca Mountain on federal land at the Nevada Test Site. After analyzing the failure at Yucca Mountain, the Article explores innovative methods of storing and disposing of nuclear waste and recommends a combination of interim long-term storage coupled with nuclear reprocessing as the answer to the nuclear waste disposal problem. Finally, the Article analyzes the remarkable bipartisan support that led to recent legislation designed to revitalize the nuclear power industry as a solution to our expanding energy needs and our obligation to reduce greenhouse gases and thus combat global warming.

INTRODUCTION

The United States, and indeed, the world, face unrelenting demand for more and more energy.[1] Unfortunately, meeting that demand with fossil fuels has resulted in escalating damage to the environment from greenhouse gas emissions that are a primary cause of global warming.[2] This dilemma has driven a search for methods of producing energy that are both clean and reliable. A surprising bipartisan political answer to that search has emerged: nuclear power.

In the United States, nuclear power produces about twenty percent of the nation's electricity.[3] While expensive to construct, nuclear plants are now less expensive to operate than most alternative clean energy sources.[4] "The cost per [kilowatt-hour] for electricity generated through a nuclear power plant is approximately $0.02," while solar and wind power are approximately $0.50 and between $0.05 and $0.08 per kilowatt-hour respectively.[5] One uranium fuel pellet produces the same energy as 17,000 cubic feet of natural

1. *See* ARMAN SHEHABI ET AL., LAWRENCE BERKELEY NAT'L LAB'Y, 2024 UNITED STATES DATA CENTER ENERGY USAGE REPORT 5–7 (2024), https://escholarship.org/content/qt32d6mod1/qt32d6mod1.pdf [https://perma.cc/SF8U-KH67].

2. *See Based on Science: Are Humans Causing Global Warming?*, NAT'L ACADS. (Aug. 12, 2021), https://www.nationalacademies.org/based-on-science/climate-change-humans-are-causing-global-warming (on file with the *Iowa Law Review*).

3. U.S. NUCLEAR REGUL. COMM'N, NRC REACTOR CONCEPTS (R-100), at 13 (2017) [hereinafter NRC MANUAL], https://www.nrc.gov/cdn/legacy/reading-rm/training/reactor-concepts-training-course.pdf [https://perma.cc/N6ZY-JNVR]; *Fundamentals*, NEI, https://www.nei.org/fundamentals [https://perma.cc/Z49N-SH2B].

4. *See* NRC MANUAL, *supra* note 3, at 12; *How a Nuclear Reactor Works*, NEI, https://www.nei.org/fundamentals/how-a-nuclear-reactor-works [https://perma.cc/3LAL-X3Z8].

5. NRC MANUAL, *supra* note 3, at 12.

gas; 2,000 pounds of coal; or 149 gallons of oil.[6] Used or spent uranium fuel can be recycled and reprocessed to obtain usable mixed oxide fuel ("MOX"), comprised of isotopes of uranium ("U") and of plutonium ("PU").[7] Alternatively, the spent fuel can be loaded into a fast breeder reactor that produces more usable U and PU fuel and other valuable nuclear materials than it expends generating power.[8]

Nuclear power plants are similar to fossil fuel plants in one major respect: Both systems use heat to produce steam that drives a turbine, which in turn powers a generator producing electricity sent to the grid.[9] The similarities end there, however. Typical nuclear power plants generate heat from a controlled nuclear fission process, fueled by an isotope of uranium, U-235, while fossil fuel plants, as the name implies, burn carbon-based substances, primarily coal and natural gas.[10] As a result, during normal operations, a nuclear power plant releases only steam from a cooling tower, while fossil fuel plants release numerous regulated pollutants, including particulates, sulfur dioxide, nitrogen oxides, carbon dioxide, and other greenhouse gases.[11]

The advantages of nuclear energy just described pose an important question for the United States: Why isn't nuclear power relied upon more heavily to meet the world's energy needs, given that it is a highly efficient, clean, and potentially renewable energy source? The answer is environmental, safety, health ("ESH"), and security concerns, some real, others only imagined.[12]

The nuclear meltdown at Three Mile Island ("TMI") froze the nuclear power industry in the United States for decades, even though no deaths or injuries occurred due to the release of radiation from the accident.[13] TMI was

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6. *Nuclear Fuel*, NEI, https://www.nei.org/fundamentals/nuclear-fuel [https://perma.cc/J8EN-3UEK].

7. *See* Aaron Szabo, *Reprocessing: The Future of Nuclear Waste*, 29 TEMP. J. SCI. TECH. & ENV'T L. 231, 238 & n.48 (2010); *Reprocessing*, NRC (May 15, 2023), www.nrc.gov/materials/reprocessing.html [https://perma.cc/ZZ5A-6M9W]; JAMES H. SALING & AUDEEN W. FENTIMAN, RADIOACTIVE WASTE MANAGEMENT 95–108 (2d ed. 2002).

8. ALAN E. WALTAR & ALBERT B. REYNOLDS, FAST BREEDER REACTORS 4 (1981). See discussion *infra* Section III.C.4 for an assessment of modern reprocessing technology, including breeder reactors.

9. *See* NRC MANUAL, *supra* note 3, at 3–12.

10. *Id.* at 15.

11. *Power Plants and Neighboring Communities*, ENV'T PROT. AGENCY (Mar. 19, 2025), https://www.epa.gov/power-sector/power-plants-and-neighboring-communities [https://perma.cc/UUQ5-CXAX]; *see also How a Nuclear Reactor Works*, *supra* note 4.

12. The perceived risk of nuclear power in the United States after the accident at Three Mile Island was many orders of magnitude greater than its actual risk as determined by experts in the field. STEPHEN BREYER, BREAKING THE VICIOUS CIRCLE: TOWARD EFFECTIVE RISK REGULATION 21, 34 (1993); J. SAMUEL WALKER & THOMAS R. WELLOCK, NRC, A SHORT HISTORY OF NUCLEAR REGULATION, 1946–2009, at 55–56 (2010), https://www.nrc.gov/docs/ml1029/ml102980443.pdf [https://perma.cc/525T-7PWC].

13. NRC, BACKGROUNDER: THREE MILE ISLAND ACCIDENT 1–2 (2022), https://www.nrc.gov/docs/ML0402/ML040280573.pdf [https://perma.cc/KCA6-WNL6]; WALKER & WELLOCK, *supra* note 12, at 53–57. Chernobyl, a true environmental catastrophe, caused the loss of human

extensively studied by the Environmental Protection Agency ("EPA"), Nuclear Regulatory Committee ("NRC"), and Department of Energy ("DOE"), as well as respected independent research institutions including Columbia University and the University of Pittsburgh.[14] All researchers concluded that the actual TMI release had negligible effects on the physical health of individuals or the environment.[15] Studies estimated that the dose to the two million members of the local public around TMI was approximately one millirem.[16] "To put this [dose] into context, exposure from a chest x-ray is about 6 millirem."[17]

Unfortunately, TMI was closely followed by the true nuclear catastrophe at Chernobyl.[18] The Chernobyl disaster caused a worldwide skepticism of nuclear power that took decades to begin to overcome.[19] But as skepticism finally lessened, disaster struck again. Some twenty years after Chernobyl, a nuclear renaissance was underway when a massive earthquake *and* tsunami struck the nuclear power plants at Fukushima, Japan, and the resulting damage to the plants caused a massive release of nuclear contaminants.[20] The Fukushima accident rekindled nuclear fear and stalled the progress made within the United States and elsewhere in advancing nuclear power as a clean and safe alternative to fossil fuel plants.[21]

Nuclear power in the United States is heavily regulated and has achieved a remarkable safety record since TMI. The Energy Reorganization Act of 1974[22] amended the Atomic Energy Act ("AEA") and created the NRC, an independent federal regulatory agency that began operations on January 19, 1975.[23] The NRC is a successor agency executing the licensing and regulation of commercial nuclear facilities previously performed by the Atomic Energy Commission ("AEC").[24] Nuclear weapons functions and nuclear energy promotion programs of the old AEC are now performed by DOE.[25] Today,

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life and such massive environmental damage that thousands of acres of land remain useless to this day. *See infra* Section II.B. The Fukushima nuclear meltdown caused some nations to abandon nuclear power altogether. *See infra* Section II.C. However, the designs and operations of these two plants were in noncompliance with international safety requirements, and even a brief examination of the three accidents demonstrates the differences. *See infra* Section II.D.

14. NRC, *supra* note 13, at 2.

15. *Id.*

16. *Id.*

17. *Id.*

18. WALKER & WELLOCK, *supra* note 12, at 58–59; *see* discussion *infra* Part III.

19. WALKER & WELLOCK, *supra* note 12, at 59; *see* discussion *infra* Part III.

20. Lincoln L. Davies, *Beyond Fukushima: Disasters, Nuclear Energy, and Energy Law*, 2011 BYU L. REV. 1937, 1941–47.

21. *Id.* at 1937–38.

22. Energy Reorganization Act of 1974, Pub. L. No. 93-438, 88 Stat. 1233.

23. WALKER & WELLOCK, *supra* note 12, at 49–51.

24. *Id.* at 49.

25. *Missions*, NAT'L NUCLEAR SEC. ADMIN., DEP'T ENERGY, https://www.energy.gov/nnsa/missions [https://perma.cc/GGA5-YX9T].

the nuclear energy industry is the most heavily regulated industry in the United States, requiring redundant safety systems designed to prevent even minor radiation releases in excess of NRC limits and EPA "as low as reasonably achievable" ("ALARA") standards.[26] NRC begins the licensing process with an evaluation of the site that assesses seismology, geology, and hydrology, among other safety issues.[27] NRC will only grant a license if the site, reactor design, and extensive safety and environmental analysis demonstrate that there is a "reasonable assurance" that the nuclear power reactor can be constructed and operated "without undue risk" to public health and safety.[28] For example, the reactor and its containment structure must be designed to withstand earthquakes, protect against flooding, and survive a collision from a commercial aircraft.[29] Since TMI, the United States has, in my opinion and that of many nuclear experts, significantly improved the safety of nuclear power plants and achieved an enviable safety record in nuclear operations.[30] Therefore, an expansion of nuclear power's role is justified and necessary if the United States is to both meet energy demand and combat global warming.

Increasing national demand for energy to run data centers used for storage and computing,[31] coupled with environmental concern for fossil fuel pollution and global warming, led to recent bipartisan support in the United States to reinvigorate the nuclear industry. Consequently, Congress passed several major statutes designed to modernize and reinvigorate the nuclear industry, while still maintaining a sound safety and environmental record.[32]

This Article details the bipartisan administrative and legislative efforts to revitalize nuclear power in the United States after a long period of stagnation.[33] In Part I, it addresses the effectiveness of NRC's ESH regulation of nuclear power in the United States; that, in turn, requires a brief explanation of how nuclear power plants are built and operated in accordance with strict ESH

26. *See* discussion *infra* Part III.

27. 10 C.F.R. §§ 100.1–100.23 (2025).

28. *Id.* § 100.10(c); *see* 42 U.S.C. §§ 2232(a), 2233(d) (2018); N. Anna Env't Coal. v. NRC, 533 F.2d 655, 665 (D.C. Cir. 1976).

29. *See* 10 C.F.R. § 50.150 (requiring aircraft impact assessments); *id.* pt. 50 app. A, Criterion 2 (detailing protection from natural disasters such as earthquake and floods).

30. NRC, *supra* note 13, at 2–3; *see* WALKER & WELLOCK, *supra* note 12, at 57–58. *See generally* CHARLES MILLER ET AL., NRC, RECOMMENDATIONS FOR ENHANCING REACTOR SAFETY IN THE 21ST CENTURY (2011), https://www.nrc.gov/docs/ML1118/ML111861807.pdf [https://perma.cc/3UE9-YJ8N] (discussing existing infrastructure and regulatory framework, offering key takeaways from the Fukushima accident, and assessing strengths and growth areas for nuclear energy in the United States).

31. For a detailed discussion of the causes of increased energy demand, and data centers' role in those increases, see generally SHEHABI ET AL., *supra* note 1; and Adam Barth, Humayun Tai, Ksenia Kaladiouk & Lawrence Heath, *Powering a New Era of US Energy Demand*, MCKINSEY & CO. (Apr. 29, 2025), https://www.mckinsey.com/industries/public-sector/our-insights/powering-a-new-era-of-us-energy-demand [https://perma.cc/TV2C-89KA].

32. *See* discussion *infra* Part IV.

33. *See* discussion *infra* Part IV.

regulations.[34] This background information facilitates a discussion, in Part II, of the consequences of the TMI accident and a comparison of TMI to the Chernobyl disaster and the Fukushima nuclear accident.[35] Members of the public who oppose nuclear power often conflate the TMI accident with true nuclear disasters and fear a catastrophic hydrogen explosion that blew the nuclear core out of the reactor building at Chernobyl, resulting in deaths, cancers, and widespread ecological damages.[36] Once informed of the differences between what happened at TMI and abroad, it becomes clear that accidents like Chernobyl and Fukushima have been rendered impossible,[37] or next to impossible,[38] in the United States, due to mandatory reactor safety design requirements and the strict ESH licensing regulations of the NRC.[39] Through a short differential analysis of the three nuclear accidents, the Article will outline the regulatory protections in the United States designed to prevent anything like what happened at Chernobyl and Fukushima from happening here.[40] In Part III, this Article confronts the remaining nuclear ESH issue in the United States—waste storage and final disposal of high-level nuclear waste and spent fuel[41] in a secure geological repository—before assessing, in Part IV, congressional and Executive Branch efforts to revitalize the nuclear power industry in the United States.[42] A conclusion recommending an expanded role for nuclear power follows.

I. REACTOR AND REGULATORY FUNDAMENTALS

Understanding the basics of nuclear reactor operations is essential to understanding nuclear safety. Moreover, understanding the regulatory scheme governing how reactors are built and operated is a prerequisite to determining if legal requirements are adequate to maintain safe operations. As such, Section I.A outlines the physical structure of a typical reactor and its safety mechanisms. Then, Section I.B lays out how the United States regulates nuclear safety and controls the releases of nuclear contaminants.

34. *See* discussion *infra* Part I.

35. *See* discussion *infra* Part II.

36. *See* discussion *infra* Part II.

37. WALKER & WELLOCK, *supra* note 12, at 58–59 (demonstrating that a Chernobyl-type accident could not occur in commercial plants in the United States).

38. *Id.* at 53–65 (discussing NRC regulation and policy changes after the TMI and Chernobyl accidents).

39. *See* discussion *infra* Parts I, II.

40. *See* discussion *infra* Part II.

41. *See* discussion *infra* Part III.

42. *See* discussion *infra* Part IV.

A. *Nuclear Reactor Fundamentals Key to Assessing Safety of the U.S. Nuclear Power Industry*

To achieve even a rudimentary understanding of the effectiveness of the ESH regulations governing nuclear power in the United States, we must first briefly discuss the technical features of nuclear power reactors licensed by NRC. [43] The heart of the reactor is the nuclear core, built with steel vertical racks that hold rods containing clad solid fuel pellets enriched with three to five percent U-235.[44] Controlled nuclear fission within the fuel rods generates heat which is used to produce steam that runs the plant's turbine and produces energy.[45]

Control rods are at the heart of the engineered safety system of a nuclear reactor. As the name implies, the control rods are used to start, control, and stop nuclear fission in the reactor core. Nuclear fission is achieved within the fuel by the release of subatomic neutrons that collide with other uranium atoms within the fuel, causing those atoms to break apart, or fission, and release heat.[46] Control rods are interspersed among the fuel rods of a typical reactor and are ordinarily loaded with boron or other nuclear "poisons."[47]

The control rods, which absorb neutrons that would otherwise collide with fissionable material in the fuel, are withdrawn to start the reactor and the fission process, or partially inserted to control the number of fissions and amount of power generated.[48] When the control rods are fully inserted into the reactor fuel vessel, nuclear fission is stopped.[49] Stopping the fission reaction by use of the control rods is called a "trip" or "scram."[50]

The nuclear core is surrounded by water in a steel reactor vessel which, together with the fuel cladding itself, serve as initial barriers to the release of radioactivity into the environment in the event of a major accident.[51] Water is pumped into the reactor building from a river or other water source after any necessary treatment. Water serves three purposes in the nuclear plant. First, heat from the fission reaction is used to convert the water in the reactor vessel into steam to run the turbine.[52] Water also surrounds the fuel rod assembly

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43. See generally NRC MANUAL, *supra* note 3, for a fuller technical description of nuclear power plants and the operation of the two most prevalent types of reactors in the United States: boiling water reactors ("BWR") and pressurized water reactors ("PWR"). Most of the background information presented in this Section pertains to both types of reactors but there are certain technical differences, mostly irrelevant for our purposes, between the two types of reactors. Unless stated otherwise, the information presented applies to BWR reactors, or both BWR and PWR.

44. *Id.* at 32.

45. *Id.* at 34–35.

46. *Id.* at 37.

47. *Id.* at 38–39.

48. *Id.*

49. *Id.* at 42–43.

50. *Id.*

51. *Id.* at 41–42.

52. *Id.* at 34–35.

and serves as a "moderator" that slows neutrons released during fission, and thus increases the number of nuclear collisions necessary to sustain the fission reaction.[53] Finally, in an emergency, additional water, sometimes with added boron, serves as a coolant to counteract the remaining decay heat generated even after the control rods are fully inserted during an emergency.[54]

The steel reactor vessel itself is often encased in a concrete barrier. NRC licensed reactors also have a steel and concrete "containment" structure or building surrounding the entire reactor assembly.[55] Containment structures are the final physical barrier to the release of radiation to the environment.[56]

Heat from the nuclear fission in the fuel rods produces steam which is piped to a separate building housing the turbine and generator previously described.[57] Operators run the plant from a control room in a building isolated from the reactor so they can maintain control even during emergency conditions.[58] In addition, emergency coolant systems (pumps, coolant water, and liquid boron) are usually housed in a separate building, often with other emergency equipment such as backup generators to run coolant water pumps in the event of a power outage.[59]

Nuclear reactors licensed in the United States are designed to provide "defense in depth" to avoid major accidents.[60] That starts with the design and engineered barriers: (1) solid fuel pellets that are clad in steel to withstand about two thousand degrees of heat from the fission reaction; (2) steel reactor vessel shielding; and (3) a concrete containment building.[61] A second line of defense is engineered backup safety systems: the control rods themselves[62] and the emergency cooling systems in the event of an emergency.[63] Additional lines of defense are operator controls, and emergency procedures in the event of an incident within the reactor building.[64] While reactors require humans to start the fission process, the reactor automatically shuts down when there is a safety issue.[65]

53. *Id.* at 34–35, 40.

54. *Id.* at 39–41, 58–61.

55. *Id.* at 99. Containment requirements for all reactors licensed in the U.S. are detailed at 10 C.F.R. pt. 50 app. A, Criterion 16—Containment design and Criterion 50—Containment design basis (2025).

56. NRC MANUAL, *supra* note 3, at 19.

57. *Id.* at 21. As noted previously, PWRs operate slightly differently. *Id.* at 21–22.

58. 10 C.F.R. pt. 50 app. A, Criterion 19—Control room.

59. NRC MANUAL, *supra* note 3, at 92–93.

60. *See* MARY DROUIN, BRIAN WAGNER, JOHN LEHNER & VINOD MUBAYI, NRC, HISTORICAL REVIEW AND OBSERVATIONS OF DEFENSE-IN-DEPTH 1-1 to 1-3 (2016).

61. *See* NRC MANUAL, *supra* note 3, at 19, 41, 63.

62. *Id.* at 42–43.

63. *Id.* at 38–39, 57, 59.

64. *Id.* at 57, 59–61.

65. *Id.* at 25.

B. U.S. REGULATION OF RELEASES OF RADIOACTIVE MATERIALS

To build a reactor in the United States, the owner must pass an unparalleled regulatory gauntlet designed to protect ESH. In addition to the statutory requirements of the Atomic Energy Act, as amended, NRC has promulgated extensive regulations which occupy two volumes of the Code of Federal Regulations.[66] Those licensing regulations and numerous design and operational requirements cannot be analyzed in detail here. However, the essential nuclear facility ESH protections can be summarized to facilitate an assessment of NRC's safety record.

The prospective nuclear plant owner must first obtain approval of the site's suitability, then secure design certification, and finally obtain a construction permit and an operating license. This can only occur after securing NRC approval of the Safety Analysis Report ("SAR") for the plant and the plant's environmental impact documentation.[67] The process often takes years or even a decade to complete because the NRC's primary goal is "to protect health and to minimize danger to life [and] property."[68] As this Section demonstrates, NRC will not license a reactor without a demonstration that the plant is designed, and can be operated, to meet strict ESH standards, including radiological release limits. NRC and EPA both play a major role in setting these radiation exposure limits.

1. EPA Numerical Radiation Standards for Nuclear Operations

EPA limits harmful ionizing radiation[69] exposure to off-site individuals as a result of nuclear fuel operations.[70] EPA also limits the total quantity of specific radioactive materials that may enter the environment from the nuclear fuel cycle.[71] Both EPA and NRC regulations measure releases of ionizing radiation in radiation effective dose equivalents[72] ("rem").[73] A millirem ("mrem") is one thousandth of a rem. The government's radiation limits, measured in rems, account for differences in the amounts of biological damages caused by different types of ionizing radiation—particles like alpha particles and neutrons, which have mass, compared with more penetrating

66. *See generally* 10 C.F.R. pts. 50–199 (2025).

67. *See generally id.* pts. 50, 52.

68. 42 U.S.C. § 2201(i); *see id.* § 2201(b).

69. Ionizing radiation is harmful radiation, capable of damaging human tissue and organs; if ionizing radiation exposures are significant or long-term, they can cause cancer or death. *See* NRC MANUAL, *supra* note 3, at 123–24.

70. *See* 40 C.F.R. §§ 190.01–190.02, 190.10(a) (2024).

71. *See id.* § 190.10(b).

72. Formerly expressed as "roentgen equivalent man." NRC MANUAL, *supra* note 3, at 267.

73. See *id.* at 108–25 for a detailed explanation of ionizing radiation, how it is measured, and the damage it can cause to humans.

gamma and x-rays, for example.[74] Mastery of radiation terms and limits requires some technical knowledge, but a layperson can best understand EPA and NRC standards as limits on the amount of potentially harmful ionizing radiation a nuclear facility may release from the plant, taking into account the health and safety of nuclear workers and the public outside the boundaries of the nuclear plant.[75]

Nuclear operations covered by EPA standards must be conducted so that a member of the public receives a limited additional annual dose equivalent to various parts of the body: no more than 25 mrem (0.025 rem) "to the whole body" (skin), "75 mrem to the thyroid, and 25 [mrem] to any other organ."[76] EPA also limits the amount of specific radionuclides that nuclear facilities may release to the environment.[77] Since these are strict liability limits designed to protect ESH, EPA need not prove direct harm to demonstrate that a nuclear operation has violated its regulations.[78]

EPA is also charged with standard setting for management and storage of spent nuclear fuel and nuclear waste at DOE-designed and NRC-regulated repositories.[79] At the start of the nuclear fuel cycle, EPA sets standards for the control of wastes at uranium mill tailings sites.[80] Finally, EPA is the principal advisor to the President regarding radiation matters and provides "guidance for all [f]ederal agencies," particularly the NRC and DOE, "in the formulation of [their] radiation standards."[81]

The stringency of EPA and NRC radiation limits for nuclear operations is best illustrated by comparison to actual doses received by U.S. residents from natural and medical sources. An individual member of the public within fifty miles of a nuclear power plant receives, on average, about 620 millirem per year from all sources,[82] of which only 0.01 mrem comes from nuclear

74. *Id.* at 114. An alpha particle is a product of nuclear fission *Id.* at 111. It is identical to a helium nucleus which contains two protons and two neutrons. *Id.* at 111, 277. The particle is large, slow moving, and less penetrating compared to neutrons or gamma rays. *Id.* at 111. It can be stopped by clothing and its principal threat to health is posed when inhaled or ingested. *Id.* Neutrons have much less mass than an alpha particle but are responsible for fission and can do biological harm. *Id.* at 112. Gamma rays have no mass, move at the speed of light, and are extremely penetrating, stopped only by proper shielding like reactor containment or lead. *Id.* at 113. Rem dose limits take into account these differences in the potential for harm. *Id.* at 114.

75. *See id.* at 124–25.

76. 40 C.F.R. § 190.10. To view key parts of the EPA radiation protection program for nuclear operations, see *id.* §§ 190.01–190.02, 190.10.

77. *Id.* § 190.10(b).

78. *See id.*

79. *See* 42 U.S.C. § 10141(a)–(b); 40 C.F.R. pt. 191. The repository was never built with major consequences for the nuclear industry. *See infra* Part III.

80. 42 U.S.C. §§ 2022(a)–(b), 7918(a)(1); 40 C.F.R. pt. 192.

81. 42 U.S.C. § 2021(h).

82. NRC MANUAL, *supra* note 3, at 136.

operations.[83] Of the 620 mrem/year average dose, about half comes from naturally occurring radon and cosmic rays from the soil and air.[84] The other half is the result of medical and dental treatments.[85] To further put the stringency of these limits into context, a lethal dose for radiation over a short 60-day period[86] is 320 to 360 rem, not millirem.[87]

2. NRC Numerical REM Limits and ALARA

NRC has promulgated additional specific exposure and dose limits for the general public beyond the boundaries of nuclear facilities and occupational exposure and dose limits for workers within the boundaries. For example, NRC requires licensees to limit *total* exposure to each member of the public and also requires releases to comply with EPA's organ and whole-body limits just discussed.[88] Specifically, NRC limits "[t]he total effective dose equivalent to individual members of the public" from a licensed nuclear operation to less than one hundred mrem per year and two mrem in any one hour, "exclusive of the dose contributions from background radiation, from any medical administration the individual has received," and from other narrow exceptions.[89] In addition to these generalized dose standards, NRC has also promulgated specific release and dose limits for each individual radionuclide that is hazardous to health and the environment.[90]

Both EPA and NRC numerical standards are bolstered by even more restrictive targets designed to meet "As Low as Reasonably Achievable" standards ("ALARA"). For example, NRC regulations at 10 C.F.R. Part 20 introduce its radiation protection program using the ALARA principle. A licensed party "shall use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable."[91] ALARA standards are based upon economic, engineering, and other considerations, not simply dose limits designed to protect health and the environment. To implement this requirement, licensees are expected to control air emissions "such that the individual member of the public likely

83. *Frequently Asked Questions (FAQ) About Radiation Protection*, NRC (June 8, 2020), https://www.nrc.gov/about-nrc/radiation/related-info/faq.html [https://perma.cc/ZZC9-4FVH].

84. NRC MANUAL, *supra* note 3, at 134–36.

85. *Id.*

86. This lethal dose is referred to as LD50/60, which is the radiation dose which will result in half the population dying if exposed for that period. *Id.* at 123.

87. *Id.* A typical chest x-ray will add about 10 mrem, a whole-body CAT scan adds 10,000 mrem, a mammogram 72 mrem.

88. 10 C.F.R. § 20.1301(a), (e) (2025).

89. *Id.* § 20.1301(a).

90. *Id.* § 20.1101 app. A.

91. *Id.* § 20.1101(b).

to receive the highest dose will not be expected to receive a total effective dose equivalent in excess of 10 mrem (0.1 mSv) per year."[92]

The ALARA radiation target set at ten millirem is obviously more stringent than the numerical standards set by EPA and NRC as necessary to protect the public health and safety. In litigation filed by members of the public residing near Three Mile Island, the Third Circuit held that the NRC's numerical limits, *not* ALARA, set the standard of care for actions in tort based on releases from a nuclear incident at a licensed facility.[93] The enforceable numerical limits are, however, bolstered by the ALARA target which is ten times more restrictive than the other numerical limits set by NRC for the general public.[94] ALARA by its own terms is a flexible limit. However, if exceeded, the licensee must report the release and take corrective action.[95]

The NRC regulations also provide detailed protection for workers in commercial nuclear facilities by specifying radiation limits for the "whole body," as well as deep tissue and specific organ limits.[96] Worker dose limits are understandably much less restrictive than those afforded the public: Allowable annual doses are measured in rems not millirems. The higher allowable limits are deemed acceptable because workers are constantly monitored for radiation exposures and corrective action, including medical intervention, if necessary, is required when an annual dose limit is exceeded.[97]

More specifically, NRC requires licensees to control "the annual occupational dose" to individual workers to achieve the lesser of two measured limits: either a total effective dose of five rem or a dose of fifty rem to any individual organ or tissue added to the deep dose equivalent.[98] Occupational doses to the eye and whole body are limited to fifteen rem and

92. *Id.* § 20.1101(d). The maximally exposed member of the public used to measure exceedances is a hypothetical individual located at the boundary of the nuclear facility. *Id.*

93. *In re* TMI, 67 F.3d 1103, 1117–18 (3d Cir. 1995).

94. *See* 10 C.F.R. § 20.1101.

95. *Id.* § 20.1101(d).

96. *Id.* § 20.1201(a)(1)(ii)–(a)(2).

97. Radiation protection for nuclear workers begins with training and restrictions on access to hazardous areas within the plant without adequate protective clothing and equipment. *See generally id.* pt. 19 (covering training for workers participating in NRC-regulated activities). Access to radiation rooms is strictly controlled by 10 C.F.R. § 20.1602. Protective equipment such as respirators, are required where appropriate in 10 C.F.R. § 20.1703. Worker exposures are carefully monitored and tracked throughout their careers and exposure reporting is required by 10 C.F.R. § 20.1502. It is beyond the scope of this Article to present and explain all of the nuclear worker protections, but they are extensive. Moreover, in states where NRC has reached an agreement for shared responsibility for certain regulatory functions at nuclear plants, the Occupational Safety and Health Administration ("OSHA") shares responsibility to protect nuclear workers pursuant to memoranda of understanding with the NRC. The full range of such protections is beyond the scope of this Article, but detailed information is available on websites for the NRC and OSHA for those interested.

98. *Id.* § 20.1201(a)(1)(i)–(ii).

fifty rem, respectively.[99] Nuclear workers wear dosimeters and take periodic medical tests to ensure that they remain below regulatory exposure levels.[100] Records must be kept of each worker's exposure and if a limit is exceeded, the licensee must take action of its own initiative[101] or NRC may order corrective action and medical treatment for the individual.

3. NRC's Enforcement of Environment, Safety, and Health Protections

NRC has broad rulemaking authority and is authorized to promulgate regulations and issue orders it deems necessary or desirable to govern any activity at nuclear facilities "in order to protect health and to minimize danger to life or property."[102] Pursuant to that authority, the Commission has produced volumes of federal regulations governing nuclear licensees in addition to the radiation standards just analyzed.[103] The rules are designed to secure the safe construction, operation, and decommissioning of licensed facilities during the entire nuclear fuel life cycle.[104]

For these ESH protections to be meaningful, they must be vigorously enforced. The Commission possesses broad enforcement powers. It has plenary enforcement authority for any violation, found through inspection or otherwise, of the AEA, the Atomic Energy Reorganization Act, any NRC rule promulgated pursuant to those Acts, any NRC administrative order, and any license condition imposed on those who possess or use special nuclear material.[105] NRC can inspect a licensed facility at any time without notice and even has full-time compliance officers on site at nuclear power plants.[106]

NRC's enforcement authorities are of three basic types: (1) criminal referrals to the Department of Justice for serious intentional and willful violations;[107] (2) injunctive relief to prevent violations from occurring in the first place, or to halt ongoing violations;[108] and (3) civil penalties for lesser

99. *Id.* § 20.1201(a)(2)(i)–(ii). How these doses are monitored, calculated, and reported to NRC is governed by 10 C.F.R. §§ 20.1202–20.1204.

100. *See id.* § 20.1201(a)(2)(i)–(ii).

101. Details regarding how each individual worker's doses are monitored, calculated, and reported to NRC are governed by 10 C.F.R. §§ 20.1202–20.1204.

102. *See* 42 U.S.C. § 2201(b), (i).

103. *See generally* 10 C.F.R. pts. 1–199.

104. *Id.* § 1.11 (explaining that NRC's "responsibilities include . . . protecting the environment, protecting and safeguarding nuclear materials and nuclear power plants in the interest of national security, and assuring conformity with antitrust laws" through its various functions which include "standards setting and rulemaking"); *see, e.g.*, *id.* pt. 52 (creating rules for the licensing, certification, and approval of nuclear power plants, including how licenses are issued and how they are terminated when a power plant ceases operations and begins decommissioning).

105. 42 U.S.C. §§ 2271, 2282 (permitting civil and criminal penalties for violations of NRC rules and licenses).

106. *See id.* § 2201(b); NRC, *supra* note 13, at 2 (showing that, since 1977, inspectors have been placed in residence at the reactors).

107. 42 U.S.C. §§ 2271–2272.

108. *Id.* § 2280.

violations that are corrected.[109] NRC's most extraordinary enforcement power is the authority to enter a nuclear facility and operate it without using Administrative Procedure Act ("APA") procedures "[i]n cases found by the Commission to be of extreme importance to the national defense and security or to the health and safety of the public."[110]

A combination of major safety improvements made by the industry since the TMI accident coupled with the strong ESH regulations enforced by NRC has produced the extraordinary safety results expected by nuclear experts. For over sixty years, the commercial nuclear industry has amassed an enviable safety record: An individual residing within fifty miles of a nuclear facility can expect, on average, *a dose of no more than 0.01 mrem per year from nuclear operations.*[111]

II. DIFFERENTIATING THE THREE MAJOR NUCLEAR ACCIDENTS

Armed with this background information, this Part presents an objective differential analysis of the three major nuclear accidents.[112] Section II.A discusses Three Mile Island. Section II.B discusses Chernobyl. Section II.C discusses Fukushima. Finally, Section II.D makes critical distinctions while comparing the accidents. The small likelihood of a major nuclear accident in the United States as evidenced in this Part, together with the scientific documentation of the nuclear industry's ESH record, were sufficient for Congress, and even many past opponents of nuclear power, to conclude that safety risks should not be the basis for stalling the nuclear revitalization in the United States.[113]

A. *The Three Mile Island Accident*

On March 28, 1979, an accident occurred at the Three Mile Island nuclear power station ("TMI"), Unit 2, near Harrisburg, Pennsylvania.[114] As a result of a series of mechanical failures combined with human errors following a scram, a loss of coolant ("LOC") in the reactor uncovered the core and about half of it melted.[115]

The immediate cause of the accident was a pressure relief valve that stuck open and allowed large volumes of reactor coolant to escape from the core—the LOC accident.[116] Panel instrumentation in the operator control room did not provide a clear picture of what was happening in the reactor.[117] Plant

109. *Id.* § 2282.
110. *Id.* § 2236.
111. *Frequently Asked Questions (FAQ) About Radiation Protection, supra* note 83.
112. *See infra* Part II.
113. *See infra* Part IV.
114. NRC, *supra* note 13, at 1.
115. *Id.* at 1–2; NRC MANUAL, *supra* note 3, at 204–09.
116. NRC MANUAL, *supra* note 3, at 205, 212.
117. *Id.* at 209.

operators failed to pick up the signs of the LOC accident, although the emergency coolant systems worked as designed. The operators, however, reduced the flow of the coolant to a trickle and by the time they realized the plant was overheating, and flooded the core with water, the core had suffered a LOC accident causing a partial meltdown of the core.[118] Reactor design prevented a hydrogen explosion. Even though a small amount of hydrogen was generated inside the containment building, it did not ignite in the absence of oxygen.[119] NRC has succinctly summarized the ESH consequences of the accident at Three Mile Island:

> In some ways, the TMI accident produced reassuring, or at least encouraging, information for reactor experts about the design and operation of the safety systems in a large nuclear plant. Despite the substantial degree of core melting that occurred, *containment was not breached*. From all indications, the amount of radioactivity released into the environment as a result of the accident was very low. . . . [A small percentage of the radioactive materials] in the reactor at the time of the accident escaped the plant. Careful epidemiological studies of the population in the region surrounding the plant revealed no increase in the incidence of cancer over a period of two decades that could be attributed to the accident.[120]

Perhaps more to the point, there were no immediate or long-term casualties as a result of the accident. Scientific analysis later determined that the maximally exposed individual member of the public received approximately one millirem of radiation—many times less than the exposure from an ordinary x-ray.[121]

B. The Chernobyl Catastrophe

On April 26, 1986, a complex combination of design flaws in a Russian-designed nuclear reactor, together with numerous operator errors, resulted in a hydrogen explosion during a test at Unit 4 of the nuclear power station in Chernobyl.[122] That explosion blew much of the radioactive core out of the reactor and dispersed radiation around the globe.[123] Two workers and twenty-eight firemen died of acute radiation exposure; long-term, an additional 1,800 thyroid cancers were attributed to the accident.[124] Approximately

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118. *Id.*

119. G.R. Corey, *A Brief Review of the Accident at Three Mile Island*, 21 INT'L ATOMIC ENERGY AGENCY BULL. 54, 54 (1979).

120. WALKER & WELLOCK, *supra* note 12, at 55–56 (emphasis added).

121. NRC, *supra* note 13, at 2.

122. *Frequently Asked Chernobyl Questions*, INT'L ATOMIC ENERGY AGENCY, https://www.iaea.org/newscenter/focus/chernobyl/faqs [https://perma.cc/Y5Y6-XMA3]; WALKER & WELLOCK, *supra* note 12, at 58.

123. NRC, REPORT ON THE ACCIDENT AT THE CHERNOBYL NUCLEAR POWER STATION (1987), at 8-1 to 8-16 (1987); *Frequently Asked Chernobyl Questions*, *supra* note 122.

124. *Frequently Asked Chernobyl Questions*, *supra* note 122.

150,000 square kilometers of land were contaminated, and thirty kilometers around the plant were designated an exclusion zone.[125] While the causes of the accident are technically complex and, therefore, difficult to fully explain here, NRC has again succinctly summarized the research findings by the International Atomic Energy Agency ("IAEA") and others and reached the following conclusions:

> On April 26, 1986, Unit 4 of the nuclear power station at Chernobyl in the U.S.S.R. underwent a violent [hydrogen] explosion that destroyed the reactor and blew the top off of it, spewing massive amounts of radioactivity into the environment. The accident occurred during a test in which operators had turned off the plant's safety systems and then lost control of the reactivity in the reactor. *Without emergency cooling or a containment building to stop or at least slow the escape of radiation*, the areas around the plant quickly became seriously contaminated, and a radioactive plume spread far into other parts of U.S.S.R. and Europe. Although the radiation did not pose a threat to the United States, one measure of its intensity in the U.S.S.R. was the level of iodine-131 around TMI were three times as high after the Chernobyl accident than they had been after the TMI accident.
>
> The design of the Chernobyl reactor was entirely different than that of U.S. plants, and the series of operator blunders that led to the accident defied belief. Supporters of nuclear power emphasized that a Chernobyl-type accident could not occur in commercial plants in the United States . . . .[126]

The Russian reactor at Chernobyl could not have been licensed in the United States based on critical design flaws. Most importantly, it was not constructed with a typical steel and concrete containment system as required in the United States.[127] Containment would have prevented the release of some, if not most, of the radiation, even if a meltdown and hydrogen explosion occurred within a contained reactor vessel.[128]

Nevertheless, if the operators had not cut off power from the grid *and* from the emergency generators, disabled emergency coolant systems, and made gross operational errors—all while violating their own test procedures,

125. *Id.*

126. WALKER & WELLOCK, *supra* note 12, at 58–59 (emphasis added). The actions by the supervisors of the experiment resulted in his criminal conviction. Celestine Bohlen, *Top Chernobyl Officials Sentenced*, WASH. POST (July 29, 1987), https://www.washingtonpost.com/archive/politics/1987/07/30/top-chernobyl-officials-sentenced/b237aaa7-1d42-405b-8d55-5e7e4e952628 (on file with the *Iowa Law Review*).

127. WALKER & WELLOCK, *supra* note 12, at 58–59; *Frequently Asked Chernobyl Questions*, *supra* note 122; *see* 10 C.F.R. pt. 50 app. A, Criterion 16—Containment design (2025); *id.* pt. 50 app. A, Criterion 50—Containment design basis. The graphite tips of the control rods also contributed to the operators' loss of control of radioactivity in the reactor.

128. *See Frequently Asked Chernobyl Questions*, *supra* note 122.

ironically, as a "safety" experiment—the world may never have equated Chernobyl with the term "nuclear disaster."[129] The Soviet cover-up during and after the accident contributed to thousands of deaths and massive amounts of land and natural resources destroyed; the area remained uninhabitable for decades.[130]

C. The Fukushima, Japan Environmental Disaster

A major nuclear accident started on March 11, 2011, and continued for several days at the Fukushima Daiichi nuclear power plants in Okuma, Japan.[131] Six reactors were located on the site, with Units 1 and 3 operating while Units 4 and 6 had been shut down previously.[132] Units 1, 2, and 3 suffered the most significant damage due to the severe Tohoku earthquake, measuring 9 on the Richter scale, and a subsequent tsunami.[133] The earthquake and tsunami were the proximate causes of the accident.[134]

The earthquake disabled the major electrical grid in the area, causing a loss of offsite power ("LOOP") to all the reactors.[135] Those that were operating automatically shut down immediately upon detection of the earthquake.[136] Moreover, a tsunami wave of forty-three to forty-six feet in height hit approximately forty minutes after the earthquake and easily surged over the plant's flood protection seawall, flooding the plant and rendering inoperative the remaining onsite backup energy sources located in the basement of the power plant.[137] The lack of electricity resulted in an inability to pump sufficient emergency coolant into the reactors after they were shutdown. As a result, the reactors were left without a means of lowering the internal temperature,

129. NRC MANUAL, *supra* note 3, at 221–22.

130. Press Release, International Atomic Energy Agency, Chernobyl: The True Scale of the Accident (Sept. 6, 2005), https://press.un.org/en/2005/dev2539.doc.htm [https://perma.cc/QSU3-YJAU]; Michael D. Lemonick, *Environment: The Chernobyl Cover-up*, TIME (Nov. 13, 1989, 12:00 AM), https://time.com/archive/6703860/environment-the-chernobyl-cover-up [https://perma.cc/FP9D-2VW5]; *Frequently Asked Chernobyl Questions*, *supra* note 122.

131. INT'L ATOMIC ENERGY AGENCY, THE FUKUSHIMA DAIICHI ACCIDENT: TECHNICAL VOLUME 1/5: DESCRIPTION AND CONTEXT OF THE ACCIDENT 2, 86 (2015), https://www-pub.iaea.org/MTCD/Publications/PDF/AdditionalVolumes/P1710/Pub1710-TV1-Web.pdf [https://perma.cc/E3S3-798S]; TOKYO ELEC. POWER CO., INC., FUKUSHIMA NUCLEAR ACCIDENT ANALYSIS REPORT 1–2 (2012), https://www.tepco.co.jp/en/press/corp-com/release/betu12_e/images/120620e0104.pdf [https://perma.cc/PU5E-7CP9].

132. TOKYO ELEC. POWER CO., INC., *supra* note 131, at 1–2.

133. INT'L ATOMIC ENERGY AGENCY, *supra* note 131, at 86–89.

134. *Timeline for the Fukushima Daiichi Nuclear Power Plant Accident*, NUCLEAR ENERGY AGENCY (Mar. 7, 2012), https://www.oecd-nea.org/news/2011/NEWS-04.html [https://perma.cc/QF6W-T4XR]; INT'L ATOMIC ENERGY AGENCY, *supra* note 131, at 2, 86; TOKYO ELEC. POWER CO., INC., *supra* note 131, at 1–2.

135. INT'L ATOMIC ENERGY AGENCY, *supra* note 131, at 2, 87.

136. *Id.* at 6.

137. *Id.* at 89.

which was rising due to decay heat.[138] The core temperature in Units 1, 2, and 3 continued to rise after the scram, and a partial meltdown occurred.[139]

Radioactive materials in the fuel rods were released into the reactor buildings, and the chemical reaction between the fuel cladding and steam generated a substantial amount of hydrogen. Operators began venting the reactors to prevent the buildup of gas that caused the explosion in the uncontained reactor at Chernobyl.[140] However, the venting was inadequate, and hydrogen explosions in Units 1 and 3 damaged the upper containment structures.[141] Another explosion occurred in the Unit 4 spent fuel pool located on the top of the reactor building.[142]

Officials were notified and the area was evacuated.[143] The compromised containment resulted in the release of a massive amount of radioactive contaminants into the environment.[144] Subsequent efforts to add water to cool the reactor led to massive drainage of radiological material that reached the Pacific Ocean.[145] The overall damage to the environment has not been fully assessed.[146] However, according to the United Nations Scientific Committee on the Effects of Atomic Radiation, "No adverse health effects among Fukushima residents have been documented that could be directly attributed to radiation exposure from the [Fukushima Daiichi nuclear power plant disaster]."[147]

D. Critical Differences in the Three Accidents

These three accidents have one thing in common: Each was the result of a loss of coolant in the reactor. The similarity ends there. The comprehensive independent accident analyses demonstrate why Chernobyl and Fukushima won't happen here in the United States, for obvious reasons. Chernobyl was an uncontained reactor with few of the design safety features required by NRC regulation; it could not have been licensed in the United States. Nevertheless, the accident would not have occurred had operators not intentionally shut down electrical power to the plant and overrode safety systems, while violating their own safety protocols in a manner never before witnessed anywhere else

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138. *Timeline for the Fukushima Daiichi Nuclear Power Plant Accident*, *supra* note 134.

139. INT'L ATOMIC ENERGY AGENCY, *supra* note 131, at 2, 89.

140. *Id.*

141. *Id.*

142. *Id.*

143. *Id.* at 96.

144. *Id.* at 2.

145. *Id.* at 2, 96, 154.

146. *See UNSCER 2020/2021 Fukushima Report: Frequently Asked Questions and Answers*, UN SCI. COMM. ON EFFECTS OF ATOMIC RADIATION, https://www.unscear.org/unscear/en/areas-of-work/fukushima-report-faq.html [https://perma.cc/C6N9-KNGG]. The massive assimilative capacity of the Pacific Ocean buffered waterborne radiation harm, and air emissions were quickly dispersed. *Id.*

147. *Id.*

in the world. The Fukushima reactors were located on the "Ring of Fire" where major earthquakes and attendant tsunamis are a constant threat.[148] The accident was the result of two major natural disasters simultaneously hitting a nuclear power facility that was improperly built in the flood plain and protected only by a seawall.[149] Portions of the reactors were even built below the groundwater level.[150] The Fukushima facility would not have met siting criteria or numerous other NRC licensing criteria for hurricane and seismic protection.[151] Few significant health effects were directly attributable to the radiation releases. Unfortunately, the early evacuation measures and mental stress on the local population did produce negative health impacts for some residents.[152]

Because of major design flaws, neither the Chernobyl nor the Fukushima plants would have been licensed in the United Sates. Nevertheless, following the three accidents, NRC has further modified and strengthened its regulatory protections to ensure that U.S. nuclear plants are safeguarded from such occurrences.[153] Most notably, NRC lowered the radiation exposure limits to the public, strengthened emergency response procedures, and expanded consideration of multiple simultaneous threats to nuclear power plants,[154] including terrorism.[155]

III. THE NUCLEAR WASTE POLICY ACT AND THE YUCCA MOUNTAIN DEBACLE

Congress has yet to overcome the remaining stumbling block to a full renaissance in the nuclear power industry: the lack of long-term storage and permanent disposal of nuclear waste in a geological repository and the resultant costs.[156] The problem stems from the United States's inability to overcome political opposition to the congressional designation of Yucca Mountain on the Nevada Test Site as the sole permanent repository for spent fuel and other high-level waste.[157] Renowned geochemist Konrad B. Krauskopf of Stanford University believed that the problem with nuclear waste disposal

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148. *See* INT'L ATOMIC ENERGY AGENCY, *supra* note 131, at 63.

149. *See id.* at 2, 63.

150. *Id.* at 62 fig. 1.2–7.

151. *See id.*; *supra* Part I.

152. *See* Frank N. von Hippel, *The Radiological and Psychological Consequences of the Fukushima Daiichi Accident*, BULL. ATOMIC SCIENTISTS, Sept. 2011, at 27, 31–33.

153. *See* NRC MANUAL, *supra* note 3, at 53–65. *See generally* Blue Ridge Env't Def. League v. NRC, 716 F.3d 183 (D.C. Cir. 2013) (discussing NRC's Fukushima taskforce recommendations for improvement in the United States).

154. *See* NRC MANUAL, *supra* note 3, at 53–65. *See generally Blue Ridge*, 716 F.3d 183 (discussing NRC's Fukushima taskforce recommendations for improvement in the United States).

155. *See, e.g.*, San Louis Obispo Mothers for Peace v. NRC, 635 F.3d 1109, 1112–15 (9th Cir. 2011) (detailing NRC's efforts to effectively address terrorist attacks in the licensing process post-9/11).

156. *See* Matthew James Braquet, Comment, *Stop Kicking the Can Down the Road: An Urgent Call to Save the United States from Nuclear Disposal*, 7 LSU J. ENERGY L. & RES. 245, 268 (2019).

157. 42 U.S.C. §10172(a).

was "political, not technological," famously foreseeing the difficulties the nation would encounter as early as 1969.[158] His words ring true today, fifty-six years later. As such, this Part addresses the seemingly intractable problems with storage and disposal of nuclear waste. Section III.A addresses the Nuclear Waste Policy Act's ("NWPA") thorny history at Yucca Mountain. Section III.B addresses litigation regarding disposal of nuclear waste at Yucca Mountain. Finally, Section III.C sets out possible solutions to the problem of waste storage and final disposal.

A. *BRIEF HISTORY OF THE NWPA AND YUCCA MOUNTAIN*

The Nuclear Waste Policy Act of 1982[159] was enacted to provide a comprehensive national program for the permanent disposal of commercial, high-level radioactive waste, including spent fuel. Recognizing that previous "[f]ederal efforts . . . to devise a permanent solution to the problems of civilian radioactive waste disposal [had] not been adequate,"[160] Congress "establish[ed] a schedule for the siting, construction, and operation of repositories" for the disposal of spent nuclear fuel and high-level radioactive waste.[161]

The NWPA mandated that the federal government assume responsibility for siting and building a permanent disposal repository for high-level nuclear waste; however, the generators and owners of the waste would bear the costs of such disposal and the burden of providing and paying for interim storage of such waste.[162] Pursuant to the NWPA, utilities owning nuclear power plants were required to enter into a nuclear waste disposal contract with the DOE, commonly referred to as the "Standard Contract."[163] Most importantly, the Standard Contract incorporated the relevant provisions of the NWPA and created an unequivocal obligation on the part of the federal government to begin taking possession and disposing of the utilities' nuclear waste no later than January 31, 1998.[164]

As originally enacted, the NWPA set forth a process by which the DOE would first identify five repositories "determine[d] suitable for site

158. SALING & FENTIMAN, *supra* note 7, at 1.

159. Nuclear Waste Policy Act of 1982, Pub. L. No. 97-425, 96 Stat. 2201 (codified as amended at 42 U.S.C. §§ 10101–10270). The NWPA was passed to secure a nuclear geological repository. *See* 42 U.S.C. § 10101(18) (defining "repository"); *id.* § 10131(b)(2) (establishing DOE's responsibility for high-level radioactive waste and spent nuclear fuel); *id.* § 10222(a)(5)(B) ("[B]eginning not later than January 31, 1998, [DOE] will dispose of the high-level radioactive waste or spent nuclear fuel . . . .").

160. 42 U.S.C. § 10131(a)(3).

161. *Id.* § 10131(b)(1).

162. *Id.* § 10222(a).

163. *Id.* For a full discussion of DOE's and nuclear plant owners' obligations under the NWPA, including the standard contract, see generally James Lockhart, Annotation, *Validity, Construction, and Application of Nuclear Waste Policy Act of 1982, Pub. L. 97-425 (codified at 42 U.S.C.A. §§ 10101 to 10270) (NWPA)*, 41 A.L.R. Fed. 2d 81 (2015).

164. 42 U.S.C. § 10222(a)(5)(B).

characterization for selection of the first repository site."[165] After DOE performed environmental assessments of each of the first five potential sites, the NWPA required the DOE to recommend three of the sites to the President for characterization as candidate sites no later than January 1, 1985.[166] In 1987, after DOE had recommended the Yucca Mountain site (and sites in Washington and Texas) to the President, Congress amended the NWPA by designating Yucca Mountain as sole location for possible development as a repository.[167] Congress ordered the DOE to "provide for an orderly phase-out of site-specific activities at all candidate sites other than the Yucca Mountain site."[168]

Following Congress's designation of Yucca Mountain as the sole potential location for the nation's nuclear waste repository, DOE initiated the site characterization, approval, review, and licensing phase of the process mandated by the NWPA.[169] For fifteen years, the DOE performed site characterization activities at Yucca Mountain; based on that scientific assessment, DOE, using EPA's standards, recommended to the President in 2002 "that Yucca Mountain be developed as the site for an underground repository for spent fuel and other radioactive wastes."[170] The State of Nevada submitted an official objection to the DOE's recommendation, as allowed by the NWPA; the filing temporarily halted consideration of the Yucca Mountain site.[171] Congress overcame Nevada's objection by passing a directive in a joint resolution that "affirmatively and finally approved the Yucca site for a repository, thus bringing the site-selection process to a conclusion."[172] That law and proclamation also proved to be wishful thinking.

B. The Yucca Mountain Litigation

Nevada and others responded by challenging the site selection of Yucca Mountain in the United States Court of Appeals for the District of Columbia

165. *Id.* § 10132(b)(1)(A).

166. *Id.* § 10132(b)(1)(B), (b)(1)(D). EPA promulgated Yucca Mountain specific radiation standards which limited the dose from a repository to a "reasonably maximally exposed individual" to no more than 15 mrem per year for 10,000 years after disposal, and 4 mrem per year from groundwater exposure for the same period. 40 C.F.R. pt. 191 (1999). Experts concluded that these protections would result in an annual risk to the maximally exposed individuals of 7 cancer fatalities per million individuals actually exposed. *Id.* NRC and DOE promulgated criteria that conformed to EPA standards. *See* 10 C.F.R. pts. 63, 963 (2025).

167. 42 U.S.C. § 10132(b)(1)(A).

168. *Id.*

169. *See id.* §§ 10133–10138.

170. SEC'Y OF ENERGY, DEP'T OF ENERGY, RECOMMENDATION BY THE SECRETARY OF ENERGY REGARDING THE SUITABILITY OF THE YUCCA MOUNTAIN SITE FOR A REPOSITORY UNDER THE NUCLEAR WASTE POLICY ACT OF 1982, at 1 (2002).

171. *See* 42 U.S.C. § 10135(b); *Yucca Mountain Research Collection: 2000–2016: The Yucca Mountain Project Grinds to a Halt*, U. LIBRS., U. NEV., RENO, https://guides.library.unr.edu/yuccamountain/timeline2000-2016 [https://perma.cc/R6UW-2HLB].

172. Pub. L. No. 107-200, 116 Stat. 735 (2002).

Circuit based on radiation limits set for the site by EPA.[173] Because DOE had not followed the National Academy of Science's recommendation that the site be secured from radiation releases for a million years, and instead adopted a ten-thousand-year standard, the court reversed DOE's decision and remanded.[174] The court dismissed all of Nevada's other claims, including the challenge to Congress's authority to designate Yucca Mountain as the sole repository site.[175]

The decision to require DOE and EPA to use the million-year standard caused four more years of delay in the handling of the Yucca Mountain application. EPA reevaluated its standard on remand, documented its use of the million-year standard in its modelling, and revised its dose limits by promulgating a two-tiered radiation protection standard in 2005 that included the mandated one-million-year compliance period. [176] The two-tier standard required a dose of no more than 15 mrem of annual radiation dose to any individual for the first 10,000 years of repository operation, followed by a 100 mrem per year dose limit from year 10,001 up to one million years, the period of geological stability, after the repository was closed.[177] NRC and DOE subsequently revised their safety regulations to conform to the million-year compliance period.[178]

Following the "million-year" reevaluation, DOE proceeded under the NWPA to "submit to the Commission an application for a construction authorization for a repository at such site."[179] Although the NWPA originally required that the DOE submit this application within ninety days of the site designation becoming effective, DOE did not submit the Yucca Mountain application until six years after the statutory deadline.[180] Finally, on June 17, 2008, four years after the *Nuclear Energy Institute* decision, DOE submitted the application, and the Commission docketed it for review by its Atomic Safety and Licensing Board ("ASLB").[181]

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173. Nuclear Energy Inst., Inc. v. EPA, 373 F.3d 1251, 1257–62 (D.C. Cir. 2004) (providing an excellent description of the federal efforts to secure a permanent repository from the passage of the NWPA in 1982 to the conclusion of the litigation in 2004).

174. *Id.* at 1315.

175. *Id.*

176. 40 C.F.R. pt. 197 (2024).

177. *Id.* pt. 197.20.

178. *Id.* It should be noted that many scientists, including those that participated in the promulgation of the original standard, found the million-year standard illusory, if not nonsensical. *See Nuclear Energy Inst.*, 373 F.3d at 1262–68 (discussing in detail why EPA chose the 10,000-year standard instead).

179. 42 U.S.C. § 10134(b).

180. *Id.*

181. *See* Department of Energy; Notice of Acceptance for Docketing of a License Application for Authority to Construct a Geologic Repository at a Geologic Repository Operations Area at Yucca Mountain, NV, 73 Fed. Reg. 53284 (Sept. 15, 2008); *Nuclear Energy Inst.*, 373 F.3d at 1257–62.

The ASLB was entering its third year of the review of the Yucca Mountain application when, on March 3, 2010, DOE inexplicably filed a motion to withdraw its application with prejudice.[182] In its motion, DOE stated that although it "reaffirms its obligation to take possession and dispose of the nation's spent nuclear fuel and high-level nuclear waste, the Secretary of Energy has decided that a geologic repository at Yucca Mountain is not a workable option for long-term disposition of these materials."[183] DOE pointedly noted that it sought to dismiss the application with prejudice "because it does not intend ever to refile an application to construct a permanent geologic repository . . . at Yucca Mountain."[184] These assertions were made without stating what legal authority or scientific and engineering principles had suddenly changed to convince DOE that the application for Yucca Mountain was unsound.[185]

States with backlogs of high-level nuclear waste and the Nevada County where Yucca Mountain is located, Nye County,[186] eventually obtained the extraordinary remedy of mandamus from the D.C. Circuit, forcing the DOE and NRC to proceed with the licensing.[187] Judge Kavanaugh reprimanded the agencies for simply defying the NWPA on numerous occasions:

> At the behest of the [NRC], we have repeatedly gone out of our way over the last several years to defer a mandamus order against the Commission and thereby give Congress time to pass new legislation that would clarify this matter if it so wished. . . . At this point, the Commission is simply defying a law enacted by Congress, and the Commission is doing so without any legal basis.
>
> We therefore have no good choice but to grant the petition for a writ of mandamus against the Commission. This case has serious implications for our constitutional structure. It is no overstatement

182. *See generally* U.S. Dep't of Energy's Motion to Withdraw, *In re* U.S. Dep't of Energy (High–Level Waste Repository), Docket No. 63-001, ASLBP No. 09-892-HLW-CAB04 (filed Mar. 3, 2010).

183. *Id.* at 1.

184. *Id.* at 3 & n.3.

185. The decision was supposedly based upon so-called policy grounds *See id.* at 4. In fact, withdrawal was due to political maneuvering by Senate Majority Leader, Harry Reid, and the illegal actions of the NRC Chairman at the time. *See* Hannah Northey, *GAO: Death of Yucca Mountain Caused by Political Maneuvering*, N.Y. TIMES (May 10, 2011), https://archive.nytimes.com/www.nytimes.com/gwire/2011/05/10/10greenwire-gao-death-of-yucca-mountain-caused-by-political-36298.html [https://perma.cc/2THT-CCWG]; Bryan Li, *Yucca Mountain: A Case Study in Political Treatment of Nuclear Waste*, STAN. U. (Feb. 19, 2016), http://large.stanford.edu/courses/2016/ph241/li-b1 [https://perma.cc/ELA5-A6J3].

186. Nye County was represented by the author in the Yucca Mountain licensing and litigation.

187. *In re* Aiken County, 725 F.3d 255, 267 (D.C. Cir. 2013). Previous efforts by the same litigants failed to obtain an *injunction* forcing DOE to proceed with the licensing. *In re* Aiken County, 645 F.3d 428, 437–38 (D.C. Cir. 2011).

> to say that our constitutional system of separation of powers would be significantly altered if we were to allow executive and independent agencies to disregard federal law in the manner asserted in this case by the Nuclear Regulatory Commission.[188]

The court, however, noted that "Congress . . . is under no obligation to appropriate additional money for the Yucca Mountain project,"[189] essentially giving Congress the power to abandon the project without killing it. But the Court also noted that "unless and until Congress authoritatively says otherwise or there are no appropriated funds remaining, the [NRC] must promptly continue with the legally mandated licensing process."[190]

Judge Randolf was even more strident in his concurring opinion, pointing out the improper political maneuvers that prevented the licensing from going forward: "Although the [NRC] had a duty to act on the application and the means to fulfill that duty, [its Chairman Jaczko] orchestrated a systematic campaign of noncompliance."[191] The Chairman ignored the four-to-one vote of his fellow commissioners to go forward, instructed staff to remove key positive findings from reports evaluating the Yucca Mountain site, and "unilaterally ordered . . . staff to terminate the review process in October 2010."[192]

We now know that Yucca Mountain was never licensed or built. The Yucca Mountain licensing was well underway when political maneuvers, orchestrated by Senate Majority Leader Harry Reid of Nevada,[193] finally stopped consideration of the Yucca repository site by cutting off congressional funding. NRC has, to this day, simply suspended its consideration of the license to comply with the court's mandamus decision.[194] Millions of documents, many of them classified, had already been submitted by the parties in scientific support or opposition to the license. [195] The witnesses on both sides were about to be deposed, and

188. *In re Aiken County*, 725 F.3d at 266–67.

189. *Id.* at 267.

190. *Id.*

191. *Id.* at 267–68 (Randolph, J., concurring). Senator Harry Reid of Nevada adamantly opposed Yucca Mountain. Gregory Jaczko worked for Reid as his director of appropriations immediately before he was appointed chairman of the NRC by President Obama. *Gregory B. Jaczko, Chairman*, NRC (Sept. 12, 2017), https://www.nrc.gov/about-nrc/organization/commission/former-commissioners/jaczko [https://perma.cc/2YE8-KJAX]. Judge Randolph also noted that NRC's inspector general and all four of the other commissioners expressed "grave concern[]" about Jascko's conduct, resulting in an investigation. *In re Aiken County*, 725 F.3d at 268 (Randolph, J., concurring). Following oral argument in the mandamus case, Jaczko resigned. *Id.*

192. *In re Aiken County*, 725 F.3d at 267–68 (Randolph, J., concurring).

193. *See* Northey, *supra* note 185; Li, *supra* note 185.

194. *See High-Level Waste Disposal*, NRC (Mar. 12, 2020), https://www.nrc.gov/waste/hlw-disposal.html [https://perma.cc/LC93-JGZH].

195. > [A]t the time the NRC suspended its licensing proceeding, 288 contentions—claims that must be resolved before the license application can be granted—remained outstanding. Over 100 expert witnesses had been identified for depositions, to address contentions on such diverse subjects as hydrology, geochemistry, climate change, corrosion, radiation, volcanism, and waste transport . . . .

then testify before the ASLB panel, when the project was unilaterally and improperly halted by Reid's former aide, NRC Chairman Jaczko.[196] Congress failed to appropriate additional funds to DOE to prosecute the license and failed to fund NRC's licensing adjudication efforts after billions of dollars of taxpayer money had been spent on the Yucca Mountain project. From time to time, some members of Congress have endeavored to resuscitate the project to no avail.[197]

Proponents of Yucca Mountain observe that political wranglings unfortunately stopped the process just before the scientific issues were to be adjudicated, firm in their belief that DOE's initial application was scientifically sound and would have been approved by the ASLB.

Because DOE was, and is still, in violation of its NWPA statutory duty to provide a repository by 1998, [198] and in default of its Standard Contract with nuclear plant owners, numerous lawsuits continue to be filed in various federal courts. Owners of nuclear power plants seek to suspend collection of nuclear waste fund fees, recover damages, recoup the costs of continued on-site storage, or some combination of these alleged financial losses.[199] Failure to build Yucca Mountain and take possession of spent nuclear fuel ("SNF") has cost the taxpayers billions of dollars beyond the $12 billion spent preparing the site for licensing before the ASLB.[200] "Payments pursuant to DOE settlements and judgments in this litigation amounted to approximately $10.6 billion as of September 30, 2023,"[201] and will continue to mount at a rate of $2 billion per year until DOE takes possession of the SNF.

In re Aiken County, 725 F.3d at 269 n.3 (Garland, J., dissenting) (citations omitted).

196. *Id.* at 267–68 (Randolph, J., concurring); *see also* text accompanying note 155. Senator Reid of Nevada adamantly opposed Yucca Mountain. Gregory Jaczko worked for Reid as his director of appropriations immediately before he was appointed Chairman of the NRC by President Obama. *See supra* note 191.

197. For example, then-President Trump's budget request for 2017 included funds to revive the licensing, but he later revoked his own request. Max Johnson, Note, *Defining Interim Storage of Nuclear Waste*, 117 NW. U. L. REV. 1177, 1194 (2023). As recently as January 2025, Nevada's senators introduced a bill entitled "Nuclear Waste Informed Consent Act," hoping to once and for all prevent the reopening of the licensing of Yucca Mountain. *See* Nuclear Waste Informed Consent Act, S. 101, 119th Cong. (2025).

198. Ind. Mich. Power Co. v. Dep't of Energy, 88 F.3d 1272, 1276 (D.C. Cir. 1996).

199. *See, e.g.*, Yankee Atomic Elec. Co. v. United States, 536 F.3d 1268, 1272 (Fed. Cir. 2008).

200. Johnson, *supra* note 197, at 1180 n.14, 1193 (citing GAO report that describes "the ongoing challenge of nuclear waste storage").

201. *See* JASON O. HEFLIN, CONG. RSCH. SERV., LSB11199, CONSOLIDATED INTERIM STORAGE OF SPENT NUCLEAR FUEL: RECENT LICENSING DECISIONS 2 (2024). There are currently 90,000 metric tons of SNF awaiting consolidated storage or a repository. Johnson, *supra* note 197, at 1180 (citing GAO reports). Because of the density of the material, the amount of the SNF expressed in weight can be deceiving. All of the spent fuel, if gathered together in one place, could be located on a football field stacked to the height of nine meters. OFF. OF NUCLEAR ENERGY, U.S. DEP'T OF ENERGY, THE ULTIMATE FAST FACTS GUIDE TO NUCLEAR ENERGY 3, https://www.energy.gov/sites/default/files/2024-02/ne-2023fastfactsguide-021424.pdf [https://perma.cc/T7BX-7CEN]. This is for illustration purposes only since it does not consider the need for

C. Approaches to the Nuclear Waste Storage and Disposal Problem

The permanent disposal of SNF, the only remaining ESH stumbling block to a new era of nuclear power, is not, however, an insuperable problem. This Section examines existing and possible solutions to manage and dispose of SNF, including medium-term storage, waste reprocessing, or a permanent waste repository.

1. At-Reactor Storage

Currently, spent fuel and high-level waste is cooled in fuel pools at the reactor site and then placed in dry cask storage facilities termed "Interim Spent Fuel Storage Installations" ("ISFSI").[202] The length of time SNF can be safely stored in ISFSIs at the reactor locations has been established by rulemaking. NRC originally promulgated a "waste confidence" rule in 1984 to satisfy the National Environmental Policy Act ("NEPA"), and the rule stated that NRC was confident the spent nuclear fuel could be safely stored for thirty years beyond the licensed life of each plant.[203] When the federal government failed to open the Yucca geologic repository in 2010, the waste confidence rule had to be updated because there was no clear date for opening a repository anywhere. Therefore, NRC revised its rule stating that spent nuclear fuel can be stored safely for at least sixty years beyond the licensed life of a facility and stated that additional on-site or off-site storage for spent fuel will be made available if needed.[204] Ultimately, NRC replaced the waste confidence rule with a Continued Storage of Spent Fuel Rule and a generic environmental impact statement ("EIS").[205] Thus, without suggesting that there are legal or policy justifications for delaying permanent disposal, Congress and DOE have several decades to solve the SNF waste storage and repository issues.

Nevertheless, SNF is backing up at reactors and the additional ISFSI construction on-site by owners is a costly endeavor currently being borne by the taxpayer.[206] Given the bipartisan consensus that nuclear power should

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shielding and safety protection provided by dry cask storage. SNF should never be placed in close proximity without licensed casks and concrete barrier systems.

202. NRC Manual, *supra* note 3, at 154.

203. 10 C.F.R. § 51.23 (1984).

204. *See* Continued Storage of Spent Nuclear Fuel, 79 Fed. Reg. 56238, 56241 (Sept. 19, 2014) (noting that NRC's sixty-year waste confidence rule was overturned by the D.C. Circuit and was replaced with Continued Storage of Spent Nuclear Fuel and a generic EIS).

205. *Id.* The new Rule and generic EIS analyze impacts for sixty years, an additional one hundred years, and indefinitely. *See id.* at 56245. Each new proposed site must also undergo a site-specific environmental assessment. *Id.*

206. *See* Heflin, *supra* note 201, at 2, David Biello, *Spent Nuclear Fuel: A Trash Heap Deadly for 250,000 Years or a Renewable Energy Source?*, Sci. Am. (Jan. 28, 2009), https://www.scientificamerican.com/article/nuclear-waste-lethal-trash-or-renewable-energy-source [https://perma.cc/M6GV-WAKF].

be revitalized,[207] and that the waste storage issue should be assessed and resolved,[208] the time to solve the problem is now.

2. Consolidating Waste Storage in Large, Private, Away-from-Reactor Facilities

Several technically sound methods exist for safely storing or disposing of SNF and high-level waste beyond the grace period provided by the Continued Storage of Spent Nuclear Fuel Rule. Expanded access to large, privately-owned waste storage facilities would allow owners to move spent fuel out of fuel pools at reactor sites—after an appropriate cooling period—and then continue to operate their reactors for longer periods of time.

NRC has used its licensing regulations under the AEA[209] to allow privately-owned, away-from-reactor storage.[210] Such facilities must pass NRC licensing and safety requirements, including an environmental review capped by the preparation of EIS and public hearings, just as is required for any other nuclear storage facility that applies for a license.[211]

Although nuclear fuel is currently stored at ten privately-owned NRC-licensed storage sites where there are no reactors,[212] litigation has slowed the adoption of this interim solution. The Supreme Court just recently cleared some legal roadblocks to these private storage facilities.[213] In 2024, the Court consolidated two cases involving challenges to NRC's licensing of private away-from-reactor storage facilities and granted certiorari in *Interim Storage Partners, LLC v. Texas*.[214] The cases involve the State of Texas's and others' ability to challenge NRC's authority under the AEA and NWPA to license such facilities for spent nuclear fuel.[215] The types of nuclear waste storage being litigated are called consolidated interim storage facilities ("CISF") designed to provide many additional decades of private commercial storage until a final repository can be sited and built.[216] Because no final repository exists for ultimate disposal of spent fuel, Texas argued that the NWPA can be read to preclude all forms of large away-from-reactor storage facilities until one such repository

207. *See infra* Part IV.

208. *See infra* Part IV.

209. 10 C.F.R. pt. 72 (2025).

210. Bullcreek v. NRC, 359 F.3d 536, 542–43 (D.C. Cir. 2004).

211. 10 C.F.R. pt. 72.

212. NRC v. Texas, 605 U.S. 665, 672 (2025).

213. *Id.* at 687–89.

214. Interim Storage Partners, LLC v. Texas, 145 S. Ct. 199, 199 (2024) (mem.).

215. *See generally* Texas v. NRC., 95 F.4th 935 (5th Cir. 2024); Texas v. NRC, 78 F.4th 827 (5th Cir. 2023).

216. *See generally Texas*, 95 F.4th 935; *Texas*, 78 F.4th 827. States are legitimately worried that such interim facilities could become permanent if a repository is never sited and built.

is built.[217] In a 6-3 decision, the Supreme Court recently held that the State of Texas was precluded from challenging NRC licensing decision because it had not participated in the licensing proceeding was therefore not an "aggrieved party" under the Hobbs Act.[218] As such, Texas could not seek judicial review of the licenses granted.

Although the decision was a procedural one, the majority opinion made it clear that the Court believes that the Atomic Energy Act contained ample authority for licensing such private storage facilities, despite the passage of the NWPA provisions for federal repositories and monitored retrievable storage facilities. The Court also cited with apparent approval the *Bullcreek* decision, which had long ago upheld the licensing of away-from-reactor storage facilities.[219]

Congress could simply moot further litigation on this issue by passing a bill which affirms NRC long-standing authority to license private away-from-reactor storage, just as the NRC now licenses private at-reactor storage facilities, private nuclear reactors, and private enrichment facilities.[220] Such a bill would probably have bipartisan support as foreshadowed by the nuclear revitalization bills analyzed in the next Section.

3. Federal Away-from-Reactor Nuclear Storage Facilities

A second option is to authorize the siting and building of even larger away-from-reactor federal storage facilities built and owned by DOE and licensed by NRC called "Monitored Retrievable Storage" ("MRS"). However, the NWPA clearly precludes MRSs until the first repository is built.[221] Thus, a substantial long-term storage solution based on the MRS concept would require Congress to amend the NWPA to allow DOE to immediately site and build multiple MRSs following the requisite NRC licensing of the facilities.

The decades-long battle over Yucca Mountain was, and is, the ultimate "not in my backyard" ("NIMBY") lesson. It foreshadows problems for the siting of MRSs even if Congress amends the NWPA. Any large-scale storage facility will likely face local opposition, primarily because residents fear that the "interim" nuclear facilities will become de facto permanent because a repository has not been sited and built.[222] Yucca was located on federal lands, the Nevada Test Site, where many nuclear detonations and tests above and below ground had already occurred. Yucca's nuclear history, together with

217. *Texas*, 78 F.4th at 831. The NWPA clearly precludes Monitored Retrievable Storage facilities as defined by the Act until the repository is built. However, other forms of storage are allowed. *See generally id.*; *Texas*, 95 F.4th 935.

218. NRC v. Texas, 605 U.S. 665, 680 (2025).

219. *Id.* at 682–87; *see also* Bullcreek v. NRC, 359 F.3d 536, 542–43 (D.C. Cir. 2004).

220. *See* 10 C.F.R. pts. 50–52, 54–55, 72, 100 (2025).

221. 42 U.S.C. § 10101; 10 C.F.R. § 72.44(g)(1).

222. *See* Johnson, *supra* note 197, at 1193–94. *See generally* HEFLIN, *supra* note 201 (discussing state challenges to NRC away-from-reactor nuclear waste licenses).

DOE's assessment of the site and congressional approval, led many to conclude that Yucca was the ideal location for a repository. Yet it was impossible to even begin the adjudication of the license before local political opposition halted the project.

Congress can overcome the NIMBY problem with MRSs in one of two ways. First, Congress could statutorily designate the location for MRSs on federal property at appropriate military installations or on DOE sites where nuclear reactor or weapons-related activity were or are conducted.[223] Obviously, Congress should also require robust ESH protections for the storage facility, just as they do for licensed ISFSIs. However, since the sites just recommended are on federal land with operators familiar with nuclear materials, many ESH protections are already in place. To prevent states and other litigants from challenging the location on suitable federal lands with adequate ESH safeguards, Congress could also preempt or limit judicial attempts to overturn the designation. Alternatively, Congress could enact a consent-based approach favored by many Democratic administrations. NIMBY concerns might be overcome if Congress provides significant financial and other incentives[224] to state and local governments willing to host MRSs on sites deemed suitable by NRC.

4. The Promising Field of Nuclear Waste Reprocessing

Another entirely different technical approach to the problem is also available and appears to be a preferrable option from the ESH perspective. Reprocessing of nuclear waste obviates the need for additional storage and is consistent with the recycling ethos of environmental advocates.[225] Five countries reprocess nuclear fuel for commercial reactors, including France, the United Kingdom, India, Japan, and Russia.[226] Reprocessing can be accomplished in one of two ways: (1) using an aqueous method known as plutonium-uranium extraction ("PUREX"), which is currently the commercial method of choice;[227] or (2) placing the spent fuel with U-238 in a breeder reactor that then produces PU and other fissionable products that can be used as fuel.[228]

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223. Congress could do so after consulting with the Departments of Defense and Energy.

224. *See* Johnson, *supra* note 197, at 1180–81. The incentives could include assurances that the facilities would not operate beyond a specified period.

225. *See* Szabo, *supra* note 7, at 241, 252. Reprocessing was abandoned, and is often opposed even now, because abundant sources of uranium are available at lesser cost, and because it produces PU, raising proliferation concerns. *Reprocessing*, *supra* note 7 (discussing regulatory staff assessment of reprocessing). It should be noted that the Resource Conservation and Recovery Act of 1976, Pub. L. No. 94-580, 90 Stat. 2795 (codified as amended at 42 U.S.C. §§ 6901–6992k), was passed even though recycling of solid and some hazardous wastes was more costly than disposal.

226. Szabo, *supra* note 7, at 241; *see* TANG & FENTIMAN, *supra* note 7, at 95–103.

227. *See* TANG & FENTIMAN, *supra* note 7, at 108–09.

228. *See generally* WALTAR & REYNOLDS, *supra* note 8, at 3–34.

The United States used both techniques for nuclear reprocessing primarily, but not exclusively, for nuclear weapons development,[229] until it was banned by President Jimmy Carter in 1977. A five-decade moratorium then ensued on the recovery of plutonium and uranium from spent nuclear fuel.[230] However, Congress has passed several statutes, including one as recently as July 2024, calling for research into advanced fuel and reactor reprocessing technologies.[231]

DOE has already dispensed millions to companies, universities, and national labs for advanced reactor and fuel research and development, and the budget for fiscal year 2026 includes even more funds for those research objectives.[232] Some of that research focuses on fast breeder technology that not only generates energy but also produces plutonium and other fuel by "burning" spent fuel rich in naturally occurring U-238. These reactors produce more nuclear fuel than they fission (burn), thus the term "breeder" reactor. They also transmute long-lived actinides in spent fuel into short-lived radionuclides, easily disposed of at low-level waste facilities.[233]

The once-through fuel process currently in use creates an enormous amount of spent fuel with no final repository for disposal on the horizon. Thus DOE, working with the private sector, has already given grants for advanced reactor demonstration projects that include reprocessing of the spent fuel using breeder technology.[234] In the forefront, TerraPower has teamed with a financial group, including Bill Gates, and obtained DOE funding and an NRC license for an advanced reactor currently under construction

229. SALING & FENTIMAN, *supra* note 7, at 103–05.

230. A brief sketch of the tortured history of the nuclear reprocessing revitalization since the initial 1977 ban is presented in Szabo, *supra* note 7, and summarized here. U.S. efforts at reinstituting a reprocessing policy have swung through the ups and downs of successive administrations. Republican administrations have been mostly supportive, while Democratic Presidents until Biden have favored continuation on the ban. Ronald Reagan removed the ban, but without the attendant government subsidies, there was no commercial interest in reprocessing since mining of the raw nuclear materials was less costly. President Clinton reinstituted the moratorium, but George W. Bush proposed a multinational program that included building fast breeder reactors and reprocessing plants in the U.S., Russia, and other known nuclear weapons states. The program, however, never received congressional funding and Barack Obama reinstituted the reprocessing ban shortly after he entered office. Nevertheless, many advanced reactor innovators continue to push for reprocessing as integral to the business plans that they had adopted. *Id.* at 231–37.

231. See *infra* Section IV.C for an in-depth discussion of the ADVANCE Act.

232. OFF. OF THE CHIEF FIN. OFFICER, U.S. DEP'T OF ENERGY, DOE/CF-0218, DEPARTMENT OF ENERGY FY 2026 CONGRESSIONAL JUSTIFICATION: BUDGET IN BRIEF 28–29 (2025).

233. Toshio Wakabayashi, *Concept of a Fast Breeder Reactor to Transmute MAs and LLFPs*, SCI. REPS. 1–2 (2021), https://pmc.ncbi.nlm.nih.gov/articles/PMC8599852/pdf/41598_2021_Article_1986.pdf [https://perma.cc/63JK-D7Z7]; *see also Advanced Reactor Demonstration Program*, U.S. DEP'T ENERGY, https://www.energy.gov/ne/advanced-reactor-demonstration-program [https://perma.cc/29ZS-UNXX]; 42 U.S.C. § 2021(c).

234. *Advanced Reactor Demonstration Program*, *supra* note 233; *see also The Plant*, TERRAPOWER, https://www.terrapower.com/natrium [https://perma.cc/ES98-AUAA].

in Wyoming at an abandoned fossil fuel site.[235] The project is designed to test and build a reactor that produces energy for 400,000 homes while replenishing the fuel in a fast reactor.[236] The system combines an advanced fast neutron Natrium reactor that uses a sodium coolant with a molten salt energy storage plant that is far less costly and more energy efficient than grid-scale battery technology.[237] Unlike large-scale reactors now in use in the United States that utilize slow neutrons, fast reactors not only produce energy, but also reprocess spent fuel rich in U-238 while doing it. DOE has many other advanced reactor and fuel projects in the pipeline.[238] Some estimate that such reactors could reduce the volume of nuclear waste by ninety percent—waste that would otherwise be disposed of in a geological repository that doesn't exist.[239]

Opposition to reprocessing has always been based primarily on non-proliferation concerns because U-235 and PU are produced in the process. These elements can be further processed into weapons-grade material: in the case of U-235, only after it is massively enriched through the gaseous diffusion process from five percent to ninety percent, which is generally considered weapons grade. [240]

Nonproliferation concerns are insufficient to halt reprocessing in the United States for several reasons. So long as the PU and U generated by reprocessing are then used for commercial nuclear fuel, and not weapons development, there is no increase in the U.S. nuclear weapons stockpile. Even so, NRC strictly regulates, and accounts for, all quantities of "special nuclear material" held by licensees, including PU and U, that are of "strategic significance" for possible weapons use.[241] It should also be noted that the United States is a signatory nation to the Treaty on the Non-Proliferation of Nuclear Weapons ("NPT"), and the reprocessing for commercial energy production is not prohibited.[242] Moreover, several nations who are signatories to the NPT, or have acceded to it, including the United Kingdom, Japan, and France, have successfully reprocessed nuclear materials for many years

235. *See The Plant*, *supra* note 234; *About TerraPower*, TERRAPOWER, https://www.terrapower.com/about [https://perma.cc/2FHY-2XRT].

236. *See TerraPower Purchases Land in Kemmerer, Wyoming for Natrium Reactor Demonstration Project*, TERRAPOWER (Aug. 16, 2023), https://www.terrapower.com/terrapower-purchases-land-in-kemmerer-wyoming-for-natrium-reactor-demonstration-project [https://perma.cc/K6GE-V5DH].

237. *Id.*

238. *Advanced Reactor Demonstration Program*, *supra* note 233.

239. *U.S. Department of Energy Releases $10 Million to Support Research on Used Nuclear Fuel Recycling Technologies*, OFF. NUCLEAR ENERGY, U.S. DEP'T ENERGY (Dec. 20, 2024), https://www.energy.gov/ne/articles/us-department-energy-releases-10-million-support-research-used-nuclear-fuel-recycling [https://perma.cc/L4CK-A2TR].

240. *Fact Sheet: Uranium Enrichment: For Peace or for Weapons*, CTR. FOR ARMS CONTROL & NON-PROLIFERATION (Aug. 26, 2021), https://armscontrolcenter.org/uranium-enrichment-for-peace-or-for-weapons [https://perma.cc/7Z9R-3BLD].

241. 10 C.F.R. pt. 74 (2025).

242. *See* Treaty on the Non-Proliferation of Nuclear Weapons art. 4, July 1, 1968, 21 U.S.T. 483, 729 U.N.T.S. 161.

without causing proliferation.[243] The export of nuclear materials, and possible proliferation as a result, is also strictly regulated in the United States by DOE and NRC,[244] and those regulations will be strengthened further with the implementation of the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act ("ADVANCE Act").[245] Finally, the United States already has sufficient stores of PU metal to meet its military needs, and any increase in that stockpile will be the result of congressional authorization approved by the President and not commercial reprocessing for use as nuclear fuel.

5. Finding a New Location for a Repository

A final solution to the nuclear waste problem is for Congress to fund and restart the licensing of Yucca Mountain. On the positive side, the site characterization work has already been completed, and the license is ready for the adjudication of Neveda's contentions, after an update on any substantial changes at the site. However, without radical changes to the NWPA, local opposition in Nevada would in all likelihood again stall or halt the licensing process.[246] There are other attractive geological options available, however.

Surprising to some, the United States owns and operates one of only three geological repositories in the world for the disposal of radioactive waste. The Waste Isolation Pilot Plant ("WIPP") "was constructed for the purpose of storing and [finally] disposing of transuranic nuclear waste (TRU) and mixed hazardous wastes which contain TRU"[247] generated by DOE's nuclear defense complex of facilities. Most of the transuranic waste remains highly radioactive for up to 24,000 years, similar to that of commercial high-level waste and spent fuel. There was very little initial public opposition to WIPP; however, the project was adamantly opposed by the State of New Mexico and various environmental groups which filed numerous lawsuits to stop the project.[248] The District Court of New Mexico accurately described the geological suitability of WIPP as a repository in the case *United States v. New Mexico*:

> [WIPP] was designed after work in the 1950's by the National Academy of Sciences which studied various methods for disposing of

243. *See* Szabo, *supra* note 7, at 241–42.

244. 10 C.F.R. pt. 110.

245. *See infra* text accompanying notes 286–87. Arguments that weapon-grade plutonium and uranium that are produced as a result of reprocessing can be stolen by terrorists or others is simply not supported by the facts. The United States has moved weapon-grade nuclear material throughout the defense complex since the end of World War II without incident. Similar security precautions would be in place for reprocessed materials, not to mention the fact that the stolen materials could not be hidden or easily transported by entities other than authorized licensees.

246. Johnson, *supra* note 197, at 1192–95.

247. United States v. New Mexico, No. CIV 99-1280M, 2000 WL 36739782, at *1 (D.N.M. July 24, 2000) (order denying motion to dismiss).

248. *Id.*

> radioactive waste, the feasibility of mined geological repositories and salt formations which could handle long-term waste isolation. A later study selected the eventual site, a 2000-foot thick salt formation known as the Salado Formation. The Salado Formation, which underlies approximately 36,000 square miles in New Mexico, Texas, Kansas and Oklahoma, was formed 220 to 250 million years ago when an ancient sea evaporated and left dissolved salts in massive layers. The Salado Formation was selected for the WIPP facility because it is regionally extensive (an indication of its stability) and also because it is isolated from other formations by impermeable beds above and below, is essentially dry, and is virtually impenetrable by water.[249]

The Salado Formation is the ideal option for a commercial SNF repository. Having survived years of litigation, WIPP was finally opened and accepted TRU waste from throughout the DOE nuclear defense complex beginning in 1999.[250]

Convincing one of the states where the Salado Formation is located to accept a repository would likely run into political opposition similar to the opposition to Yucca Mountain. That opposition could only be overcome by strong incentives, including financial payments, better education of the public on the risks involved, and perhaps congressional preemptive action that precludes states from halting the repository. Whatever the prospects are for a geological repository, the viable options for interim consolidated storage and advancements in reprocessing of SNF discussed previously indicate that storage and disposal issues should not halt the nuclear revitalization now taking place. Solutions are available if political opposition can be overcome. Moreover, even current at-reactor storage provides a multi-decades-long window to secure a solution. Meanwhile, revitalization of nuclear power is being spurred by bipartisan congressional action.

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249. *Id.* WIPP has been the subject of litigation in both federal and state courts on several occasions since it was proposed in 1980. *See generally* New Mexico v. EPA, 114 F.3d 290 (D.C. Cir. 1997) (involving a challenge to the EPA Administrator's Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with 40 C.F.R. Part 191 (1996)); New Mexico v. Watkins, 969 F.2d 1122 (D.C. Cir. 1992) (involving a challenge to Public Land Order 6232, which provided for the deposit of TRU waste at the WIPP site for test purposes); New Mexico *ex rel.* Madrid v. Richardson, 39 F. Supp. 2d 48 (D.D.C. 1999) (construing the scope of an injunction issued in 1992 and the effect of an amendment to the New Mexico Hazardous Waste Act); Sw. Rsch. & Info. Ctr. v. State, 62 P.3d 270 (N.M. Ct. App. 2002) (involving a challenge to a state permit modification).

250. *New Mexico*, 2000 WL 36739782, at *1 (describing why the NAS chose the formation as suitable for WIPP). There has been one accident of note at WIPP which resulted in the release of radiological contaminants due to a drum that was improper packed at Los Alamos before shipping. *2014 Radiological Event at the WIPP*, U.S. ENV'T PROT. AGENCY (May 14, 2025), https://www.epa.gov/radiation/2014-radiological-event-wipp [https://perma.cc/98C4-6ZVA].

IV. Recent Changes in U.S. Laws, Regulations, and Policies Trigger a Nuclear Renaissance: Will It Be Enough?

Both Congress and the last two presidential administrations have embarked on several major efforts to revitalize the nuclear industry. Those efforts go far beyond NRC's streamlining the regulatory process by allowing the licensing for construction and operating to be consolidated into a one-step licensing process.

The most recent revitalization efforts followed both a legislative and a regulatory track. Congress enacted several laws designed to stimulate improvements in advanced nuclear reactor designs, reliability, efficiency, and safety, and to reduce licensing costs and prompt major reforms in NRC's regulatory process. Just as importantly, they passed provisions designed to stimulate improvements in nuclear fuel and reprocessing. Since the Energy Policy Act of 2005, NRC had anticipated the need for regulatory reform and modernized the regulatory process while maintaining an emphasis on safety. A key NRC innovation has been a slow shift from deterministic risk assessment to probabilistic modeling techniques.[251] So many ambitious goals have been set that the challenge now will be to ensure that progress is achieved in a safe and environmentally sound manner.

A. *The Nuclear Energy Innovation Capabilities Act and the Nuclear Energy Innovation and Modernization Act*

Both the Nuclear Energy Innovation Capabilities Act ("NEICA") and Nuclear Energy Innovation and Modernization Act ("NEIMA") are remarkable from a political standpoint. During a prolonged period of extreme divisiveness between the two major political parties, the nuclear reforms were passed with bipartisan support.[252] First, in 2017, Congress passed amendments to the Nuclear Energy Policy Act of 2005 in NEICA to further advance nuclear energy research and development. [253] Many of the amendments obligated DOE to support governmental and private research and development of methods for improving all aspects of nuclear design and operation.[254] Specific

251. *See* Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors, 85 Fed. Reg. 71002 (proposed Nov. 6, 2020) (codified at 10 C.F.R. pt. 53).

252. As will be discussed in this Part, these measures were overwhelmingly supported by both Republicans and Democrats in Congress over the past eight years. NEICA passed both houses by simple voice vote. Nuclear Energy Innovation Capabilities Act of 2017, S. 97, 115th Cong. (2017). NEIMA passed the Senate by voice vote, and the House by a vote of 361 to 10. Nuclear Energy Innovation and Modernization Act, S. 512, 115th Cong. (2017). The most important reform, the ADVANCE Act passed with overwhelming political support. It passed the Senate by a vote of 88-2 and the House by a vote of 393-13. *See* Press Release, U.S. Senate Comm. on Env't & Pub. Works, SIGNED: Bipartisan ADVANCE Act to Boost Nuclear Energy Now Law (July 9, 2024), https://www.epw.senate.gov/public/index.cfm/2024/7/signed-bipartisan-advance-act-to-boost-nuclear-energy-now-law [https://perma.cc/3PVP-RUN7].

253. Nuclear Energy Innovation Capabilities Act of 2017, S. 97, 115th Cong. (2017); 42 U.S.C. §§ 15801, 16271–16275.

254. 42 U.S.C. §§ 16271–16275.

provisions mandated increased technology transfer within public and private research institutions[255] and fostered further research into nuclear fusion and "fast neutron" technology[256] that could be useful in numerous applications including reprocessing.

Congress subsequently passed NEIMA[257] in 2019 to update nuclear energy regulations, noting that existing NRC regulations in 10 C.F.R. Parts 50 and 52 "may not be suitable for advanced technologies with unique characteristics."[258] In passing NEIMA, Congress mandated reforms designed to revitalize the nuclear industry and stimulate innovation in reactor development, fuel, and waste management.[259]

NEIMA also highlighted congressional desire to streamline and modernize NRC's regulatory processes, stimulate the development of the next generation of nuclear reactors and fuels, decrease the economic burden of nuclear power licensees, and manage nuclear waste more efficiently. Congress specified that NEIMA would develop expertise and regulations to allow "innovation and the commercialization of advanced nuclear reactors," revise fee recovery provisions, and encourage "more efficient regulation."[260] NEIMA defined "advanced nuclear reactors" broadly to include fission reactors and fusion reactors without any qualification, except that such reactors incorporate "significant improvement" over reactors already in existence or under construction in 2019.[261] The improvements Congress sought were in a range of fields, starting with safety, waste reduction and improved fuel utilization, lower electricity costs, and increased facility reliability.[262]

Congress also mandated other changes it considered necessary. For example, NEIMA reduced the amount of fees, termed corporate support costs, paid each year to NRC.[263] The statute also capped other fees collected from owners and licensees, such as storage fees for spent nuclear fuel.[264] Presumably these reductions in the financial burdens on commercial plant owners will allow them to continue to operate existing plants rather than decommissioning them while also focusing on further safety improvements and technological innovation. At the same time, NEIMA authorized additional funds for research and development of the next generation of nuclear reactors and nuclear fuel addressed previously. NEIMA also targeted other

255. *Id.* § 16271(a).

256. *Id.* § 16275(c).

257. Nuclear Energy Innovation and Modernization Act, Pub. L. No. 115-439, 132 Stat. 5565 (2019) (codified as amended in scattered sections of 42 U.S.C.).

258. *See id.*; S. REP. NO. 115-86, at 5 (2017).

259. *See* Nuclear Energy Innovation and Modernization Act § 2.

260. *Id.*

261. *Id.* § 3.

262. *Id.*

263. *Id.* § 102.

264. *Id.*

reforms designed to shift the nuclear industry's focus to advanced reactors, better fuels, and more efficient and safer light water reactors ("LWRs") and small modular reactors ("SMRs").[265]

NRC, responding to the long-standing need for regulatory reform, had already anticipated the need for regulatory improvement and launched a Licensing Modernization Project ("LMP") to address problems in the regulatory framework for licensing advanced reactors.[266] LMP culminated in rulemaking which focused on developing modern risk assessment techniques as an alternative to the more inflexible deterministic risk methods which were used by NRC for decades.[267] The proposed rules explain how the new requirements are intended "to provide the necessary flexibility for licensing and regulating a variety of advanced nuclear reactor technologies and designs," as opposed to 10 C.F.R. sections 50 and 52, which were designed to regulate traditional large-scale boiling water reactors ("BWRs") and pressurized water reactors ("PWRs") as well as research reactors.[268] NRC extended its public comment period for the new Part 53 rule until February 28, 2025, and intends to comply with the December 2027 deadline imposed by Congress in NEIMA.[269]

Supplementing NEIMA, the Biden Administration's Inflation Reduction Act ("IRA")[270] also included financial support for the nuclear industry. In addition to expanding tax credit programs for nuclear, the IRA authorized funding to advance not only reactor design and operation, but also mandated NRC regulatory reforms, reactor research, and critical reevaluation of safety methodologies.[271]

Some commentators believe that NRC reforms should be focused solely on SMRs and that Congress and NRC have not done enough to stimulate this most promising form of advanced nuclear reactors.[272] SMRs are designed to be built in factories and deployed in arrays where needed and using fuels of up to twenty percent enriched U-235.[273] They are considered inherently safer due to their small size and safety enhancements that make radiation releases extremely unlikely even if there are catastrophic failures of the safety systems. For example, the SMR will be located underground in containment. Their small size reduces the number of operators that need to be present and the

265. *Id.* § 2.

266. *See* Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors, 85 Fed. Reg. 71002 (proposed Nov. 6, 2020) (codified at 10 C.F.R. pt. 53).

267. *Id.*

268. *Id.*

269. *See* 42 U.S.C. § 2133 note, section (e)(4).

270. Inflation Reduction Act of 2022, Pub. L. No. 117-169, 136 Stat. 1818.

271. *Id.* § 13105 (codified at I.R.C. § 45U).

272. *See, e.g.*, Mari Reott, Comment, *Escaping the Nuclear Ice: The Nuclear Regulatory Commission's Race to Regulate Small Modular Reactors*, 128 PENN ST. L. REV. 225, 228–29 (2023).

273. *See id.*; *see also* Sulgiye Park & Rodney C. Ewing, *US Legal and Regulatory Framework for Nuclear Waste from Present and Future Reactors and Their Fuel Cycles*, 48 ANN. REV. ENV'T & RES. 713, 727 (2023).

higher enrichment levels of up to twenty percent U-235 make the need for refueling much less frequent and will result in less waste.[274]

B. COMMERCIAL EFFORTS TO DEVELOP ADVANCED REACTORS AND FUELS

Many advancements in reactor and fuel design are currently underway. TerraPower's fast reactor with significant efficiency and ESH improvements in both reactors and fuel technologies was discussed previously.[275] Moreover, similar improvements in large-scale reactors have already been designed and built. The first two advanced reactors ever licensed and built in the United States have just begun operations in Georgia.[276] They are among the first wave of "advanced reactors" even though they do not meet the definition in NEIMA because construction began before 2017. The Biden Administration's Secretary of Energy, Jennifer Granholm, praised the new reactors while touring the Georgia plants; she called for more nuclear power plants to be built in the United States in the fight against climate change.[277] The two new AP1000 reactors at the Georgia plant were built by Westinghouse and have been equipped with many new safety and efficiency features.[278] In addition to the containment vessel, the plant is housed in double containment with a "shield building."[279] The plant can withstand hurricanes and is seismically qualified to resist earthquakes encountered in the region.[280]

Most importantly, the plant's footprint is much smaller and relies on "passive safety" systems.[281] The main control rods are automatically dropped in by gravity, not driven in electrically, in the case of an emergency—all without the need for a human operator. [282] The emergency cooling water systems use gravity flow to safely slow or halt reactor operations in the event of an emergency, even during a total loss of power at the plant.[283] The size of the plant, length of piping, and the number of valves and pumps have all been

274. The legal, technical, and safety concerns with advanced reactors are addressed in detail by Professors Sulgiye Park and Rodney C. Ewing at Stanford University in their article for the Annual Review of Environment and Resources. *See generally* Park & Ewing, *supra* note 273.

275. *See supra* Section III.C.4.

276. Jeff Amy, *US Energy Secretary Calls for More Nuclear Power While Celebrating $35 Billion Georgia Reactors*, ASSOCIATED PRESS (Aug. 15, 2024, 12:40 PM), https://apnews.com/article/georgia-nuclear-plant-energy-secretary-granholm-05a6e2444a8b5a9e9c7c61b111b87192 [https://perma.cc/4G69-Y357].

277. *Id.*

278. *AP1000 Nuclear Power Plant - Passive Safety Systems*, WESTINGHOUSE, https://westinghousenuclear.com/energy-systems/ap1000-pwr/safety/passive-safety-systems [https://perma.cc/M6EF-96G2].

279. *AP1000 Plant Safety Systems and Timeline for Station Blackout*, WESTINGHOUSE, https://westinghousenuclear.com/data-sheet-library/ap1000-plant-passive-safety-systems-and-timeline-for-station-blackout [https://perma.cc/HD4V-JRF9].

280. WESTINGHOUSE, AP1000 DESIGN CONTROL DOCUMENT 3.2-1 (2011).

281. *Id.*

282. *Id.*

283. *Id.*

significantly reduced, which simplifies operational control and enhances safety.[284] There are so many electrical, coolant, and other operational upgrades that it is beyond the scope of this Article to cover them all in detail. The large number of hardware and software safety upgrades that have been tested in previous Westinghouse reactors (AP600) make the AP1000 one of the safest on earth.[285]

Additionally, the once-through fuel process currently in use in the United States creates an enormous amount of spent fuel with no final repository for disposal on the horizon. Therefore, the research and development on other promising forms of reprocessing continues. In addition to TerraPower's fast reactor project in Wyoming, Orano and SHINE Technologies have entered into a memorandum of understanding to build a pilot commercial reprocessing facility designed to extract ninety-nine percent of usable PU and U from spent fuel.[286] Orano is the world leader in reprocessing outside the United States.[287] SHINE's CEO has stated, "It's not just about recycling plutonium because there's a tremendous amount of other valuable isotopes in the waste stream that are beneficial to humans."[288] Energy Secretary Jennifer Granholm stated in October of 2022 that "[r]ecycling nuclear waste for clean energy generation can significantly reduce the amount of spent fuel at nuclear sites, and increase economic stability for the communities leading this important work."[289]

C. The ADVANCE Act, the Most Recent and Comprehensive Attempt at Nuclear Revitalization

Apparently dissatisfied with the progress of the Executive Branch in meeting the goals for innovation established in NEICA and NEIMA, Congress recently passed, and President Biden signed, the bipartisan Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act ("ADVANCE Act").[290] The Act aggressively pursues the two main themes of the previous statutes: regulatory reform and innovation of advanced reactors and fuels.

284. T.L. Schulz, *Westinghouse AP1000 Advanced Passive Plant*, 236 NUCLEAR ENG'G & DESIGN 1547, 1551 (2006).

285. *See id.*

286. *Unlocking the Promise of Clean Energy Through Nuclear Waste Recycling*, SHINE, https://www.shinefusion.com/blog/unlocking-the-promise-of-clean-energy-through-nuclear-waste-recycling [https://perma.cc/ZX6U-6TW4].

287. *Id.*

288. David Kramer, *US Takes Another Look at Recycling Nuclear Fuel*, 77 PHYSICS TODAY 22, 25 (2024).

289. *DOE Awards $38 Million for Projects Leading Used Nuclear Fuel Recycling Initiative*, U.S. DEP'T ENERGY (Oct. 21, 2022), https://www.energy.gov/articles/doe-awards-38-million-projects-leading-used-nuclear-fuel-recycling-initiative [https://perma.cc/8YWD-ESYF].

290. Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act of 2024, Pub. L. No. 118-67, 138 Stat. 1448 (supplementing and amending 42 U.S.C. §§ 2155(b), 2201, 2215, 10109). For convenience, hereinafter cited as "ADVANCE Act" with the section of the public law being referenced. For example, ADVANCE Act § 403.

Supporting those themes, the Act: (1) directs NRC to take steps to modernize and accelerate its licensing process, with deadlines and reporting requirements; and (2) amends NEIMA to further incentivize developments in advanced reactor technology and fuel reprocessing.[291] This is a shift from a "once through and dispose" fuel cycle to a twice or multiple-through fuel process that greatly reduces the amount of spent fuel and high-level waste by recycling.[292]

According to the principal authors of the statute, the ADVANCE Act will drive nuclear technology and development growth. First, it will promote American nuclear energy leadership by "[e]mpowering the Nuclear Regulatory Commission to lead in international forums to develop regulations for advanced nuclear reactors" and "[d]irecting the Department of Energy to improve its process for approving the export of American technology to international markets, while maintaining strong standards for nuclear non-proliferation."[293] Second, it will:

> Support Development and Deployment of New Nuclear Energy technologies by: Reducing regulatory costs for companies seeking to license advanced nuclear reactor technologies[, c]reating a prize to incentivize the successful deployment of next-generation reactor technologies[, and r]equiring the NRC to develop a pathway to enable the timely licensing of microreactors and nuclear facilities at brownfield and retired fossil fuel energy generation sites.[294]

The ADVANCE Act also targets system-wide improvements. It strengthens America's nuclear energy fuel cycle and supply chain infrastructure by enhancing NRC's ability to license advanced nuclear fuels that can increase safety and economic competitiveness for reactors by tasking NRC "to evaluate advanced manufacturing techniques to build nuclear reactors better, faster, [and] cheaper."[295] As NRC does so, it will have more flexibility to manage its resources and modernization efforts, while also adding staffing.[296]

For example, to overcome the backlog of license reviews, the NRC Chairman has been given powerful new personnel management authority. Most importantly, the Chair has been given authority to "recruit and directly appoint exceptionally well-qualified individuals" to improve and speed up the NRC's licensing process.[297] Up to 210 permanent and 20 term-limited scientists, engineers, or other critical need personnel may be hired under this

291. *Id.* §§ 202, 207.

292. *See id.*

293. Press Release, U.S. Senate Comm. on Env't & Pub. Works, Carper, Capito, Whitehouse Applaud Senate Passage of Nuclear Energy Bill, the ADVANCE Act (June 18, 2024), https://www.epw.senate.gov/public/index.cfm/2024/6/carper-capito-whitehouse-applaud-senate-passage-of-nuclear-energy-bill-the-advance-act [https://perma.cc/88KQ-NEK6].

294. *Id.*

295. *Id.*

296. *Id.*

297. ADVANCE Act § 502.

excepted service authority with their salary set by the Chair, not to exceed Level III of the Executive Schedule.[298]

The ADVANCE Act goes much further than previous congressional attempts to stimulate innovation and achieve regulatory reform in the nuclear licensing process. Some of its features are quite striking. Foremost is the Act's mandate to modernize and streamline nuclear reactor environmental reviews under NEPA.[299] Pursuant to NEPA, "major federal actions significantly affecting the quality of the human environment" require the federal agency proposing the action to first prepare an Environmental Assessment ("EA") and possibly an Environmental Impact Statement ("EIS") that analyzes the impacts and alternatives to the project, including no action.[300] An NRC license is a major federal action and the applicant is required to submit its own environmental report[301] covering the impacts of the proposed project as the first step in NRC's meeting its environmental obligations under NEPA.[302] NRC uses the applicant's environmental report to prepare its own EA and EIS.[303] NRC's licensing and other "final" agency actions under NEPA are subject to judicial review under the APA.[304]

NEPA is a procedural law. It does not dictate that a license be declined, even if granting the license significantly impacts the environment. Nevertheless, NEPA has had a profound effect on the methods NRC uses and the time it takes to make licensing decisions. On the positive side, NEPA legitimately requires a "hard look" by any federal agency assessing a project's or regulation's impacts on the environment and also requires agency consideration of possible alternatives to taking the action.[305] On the negative side, NEPA has been the "instrument of choice" used by opponents of the nuclear power industry for decades in an effort to stop or at least delay construction of nuclear power plants in the United States with allegations of inadequate environmental reviews or defective EISs.[306]

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298. *Id.* Such employees may also be given $25,000 signing bonuses. *Id.* Existing staff are eligible for a salary bonus of up to $25,000. *Id.*

299. National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321, 4331–4336(e), 4341–4347, 4361–4370(j), 4370(m).

300. *Id.* § 4332(2)(C).

301. *See, e.g.*, 10 C.F.R. §§ 51.28, 51.45–51.50 (2025).

302. *Id.* §§ 51.28–51.31, 51.45.

303. *E.g.*, *id.* §§ 51.29, 51.90.

304. Administrative Procedure Act, 5 U.S.C. § 706.

305. *See* Thomas J. Miles & Cass R. Sunstein, *The Real World of Arbitrariness Review*, 75 U. CHI. L. REV. 761, 761 (2008).

306. For example, see the decades-long series of NEPA challenges by the group San Luis Obispo Mothers for Peace to stop construction and operation of the San Luis Obispo power plant. San Luis Obispo Mothers for Peace v. NRC, 789 F.2d 26, 34–37 (D.C. Cir. 1986); San Luis Obispo Mothers for Peace v. NRC, 449 F.3d 1016, 1019–21 (9th Cir. 2006); San Luis Obispo Mothers for Peace v. NRC, 635 F.3d 1109, 1111–12 (9th Cir. 2011); San Luis Obispo Mothers for Peace v. NRC, 100 F.4th 1039, 1044–49 (9th Cir. 2024).

Congress is now firmly committed to streamlining the NEPA process for nuclear power plants. NRC must report to Congress within 180 days of the passage of the ADVANCE Act its actions to reduce the regulatory burden of NEPA compliance by making the process more efficient.[307] The NRC, per Congress, must consider: (1) amending NRC's NEPA regulations[308] to allow the NRC to use, on a case-specific basis, EAs rather than full EISs, and generic EISs for advanced reactor licensing; (2) establishing new categorical exclusions from NEPA through rulemaking and increasing reliance on the use of existing "categorical exclusions"; (3) increasing reliance on existing environmental studies and impact statements prepared either by NRC, or by other federal agencies, and avoiding duplication of environmental reviews by multiple agencies; (4) streamlining the assessment of alternatives to the project required in an EIS; (5) increasing the use of "mitigating" factors to reduce the impact of plant features to a level that allows a "finding of no significant impact" where appropriate; (6) placing greater reliance on environmental studies available from federal, state, and local governments as well as private entities; (7) streamlining the required NEPA consultation process with applicant and interested parties; and (8) achieving greater efficiency by use of real-time online technologies for review and revision of environmental technologies.[309] These recommended procedures appear to be an effort to rectify the years, sometimes decades, of delay triggered by serial NEPA litigation, such as the experience at San Luis Obispo and elsewhere during the nuclear plant boom in the 1970s.[310]

Similarly, Congress has directed NRC to increase its use of the combined licensing processes already available to it.[311] The one-step process has significant efficiency advantages over the separate "construction permit" and "operating licensing" two-step process.[312] For power plants to be located on a site of existing nuclear facilities, NRC is instructed to use data and information already used for the previous facilities to the extent that it is "practicable."[313]

D. *Recent Executive Orders Designed to Accelerate Nuclear Revitalization*

On May 23, 2025, President Trump signed four executive orders designed to rapidly move DOE, NRC, and the private sector forward in revitalizing nuclear power in the United States.[314] The orders support, and in

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307. ADVANCE Act § 506

308. 10 C.F.R. pt. 51.

309. ADVANCE Act § 506(b)(2).

310. *See supra* note 306 and accompanying text.

311. 10 C.F.R. §§ 52.71–52.110.

312. *Id.* § 50.23; ADVANCE Act § 505.

313. ADVANCE Act § 505 (amending 42 U.S.C. § 2235).

314. Exec. Order No. 14299, 90 Fed. Reg. 22581 (May 29, 2025) ("Deploying Advanced Nuclear Reactor Technologies for National Security"); Exec. Order No. 14300, 90 Fed. Reg.

many cases go well beyond, previous efforts to implement the ADVANCE Act, NEICA, and NEIMA.[315] The orders contain aggressive deadlines and numerous substantive provisions designed to reinvigorate all federal nuclear programs responsible for research, testing, and deployment of nuclear reactors and nuclear waste reprocessing facilities using advanced technologies.[316]

While many of the initiatives are technically and legally sound, former NRC commissioners and others have legitimately raised safety concerns with questionable reforms, especially Executive Order 14300 (the "Order"), which instructs NRC to comprehensively reform its staffing, management, and safety regulations.[317] That Order exceeds the improvements authorized by the ADVANCE Act and blames NRC and its ESH safeguards for the lack of progress in revitalizing the nuclear power industry.[318]

In the introductory paragraphs of the Order, the President openly criticized NRC commissioners' and staff's strong safety culture and the NRC licensing regulations.[319] The specific NRC staffing and ESH provisions of the Order are deeply troubling. NRC was ordered to reduce the personnel and functions of the Advisory Committee on Reactor Safeguards ("ACRS") "to the minimum necessary" and to limit ACRS review to licensing activities that are novel or noteworthy.[320]

NRC, an independent agency, was also ordered to reorganize its structure and its entire staffing in consultation with the widely criticized Department of Government Efficiency ("DOGE") so that it does "not unduly restrict the benefits of nuclear power."[321] The Order includes a "reduction[] in force" of NRC staff while at the same time demanding the creation of a new NRC "team of at least 20 officials to draft" comprehensive new agency regulations, including those governing licensing and nuclear safety.[322] NRC must propose the new rules by February 23, 2026 and publish final rules by November 23, 2026.[323]

22587 (May 29, 2025) ("Ordering the Reform of the Nuclear Regulatory Commission"); Exec. Order No. 14301, 90 Fed. Reg. 22591 (May 29, 2025) ("Reforming Nuclear Reactor Testing at the Department of Energy"); Exec. Order No. 14302, 90 Fed. Reg. 22595 (May 29, 2025) ("Reinvigorating the Nuclear Industrial Base").

315. See analysis of those statutes' provisions, *supra* Sections IV.A–.C.

316. *See generally* Exec. Order 14299, *supra* note 314; Exec. Order 14300, *supra* note 314; Exec. Order 14301, *supra* note 314; Exec. Order 14302, *supra* note 314.

317. Exec. Order 14300, *supra* note 314, § 4, at 22588; *see* Spencer Kimball, *Trump's Nuclear Power Push Weakens Regulator and Poses Safety Risks, Former Officials Warn*, CNBC (July 17, 2025, 2:14 PM), https://www.cnbc.com/2025/07/17/trumps-nuclear-power-push-weakens-regulator-and-poses-safety-risks-former-officials-warn.html [https://perma.cc/T4VX-Q44R].

318. *See* Exec. Order 14300, *supra* note 314, § 1, at 22587.

319. *Id.*

320. *Id.* § 4, at 22588.

321. *Id.*

322. *Id.*

323. *Id.* § 5, at 22588.

In rewriting its rules, NRC must establish fixed deadlines for license evaluations and, most ominously, reconsider its radiation exposure model and rules.[324] While the licensing deadlines themselves are problematic, especially when NRC staffing is scheduled be cut, the signal to retreat from long-standing, science-based radiation protections is a major, and potentially harmful, mistake. NRC has already proposed rules which allow flexible, risk-informed licensing, where appropriate, rather than deterministic risk assessment.[325] However, the mandated retreat from the ALARA goals and enforceable numerical standards set by scientific experts at EPA and NRC would be a major mistake that could lead to accidents endangering the public.[326] This specific mandate is particularly ill-advised since the strict enforcement of the radiation protection and safety standards examined in Part I of this Article is one of the key reasons that the nuclear power industry achieved an exemplary safety record after TMI. The strict standards and their enforcement also led to overwhelming support for nuclear revitalization in Congress and among many informed members of the public. Proponents of safe nuclear power will want to see if the safety standards can be revised and implemented without eroding ESH protections or bipartisan support for nuclear revitalization.

The mandates to reduce staff and rewrite licensing regulation in accordance with the President's wishes also clearly encroach on NRC's independence and legal authority. NRC is an independent agency administered by a bipartisan group of five commissioners that have expertise in nuclear matters; they cannot be removed legally except for cause.[327]

324. *Id.* § 5, at 22589. Setting fixed deadlines for all forms of license reviews is troubling in and of itself. Nuclear experts know that fixed deadlines for licensing decisions in many cases are inimical to nuclear safety. Enforceable deadlines may be appropriate where proven reactor technology is to be collocated with other reactors existing at the same site, or where a request is made to extend the license of an existing reactor with a good safety record. But many licenses require far more than two years to adequately address the ESH issues raised, especially new technologies that are the focus of the Order.

325. *See* Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors, 85 Fed. Reg. 71002 (proposed Nov. 6, 2020) (codified at 10 C.F.R. pt. 53).

326. *See* Exec. Order 14300, *supra* note 314, § 5(b), at 22589.

327. No more than three commissioners may be of the same party. 42 U.S.C. § 5841(b)(2). Each commissioner serves a five-year term and cannot be removed except for cause. *Id.* § 5841(c). President Trump already encroached on the independence of the NRC when he fired Commissioner Christopher Hanson, a Biden appointee without discernable "cause" recognized by the law governing removal of heads of independent agencies. Geoff Brumfiel, *President Trump Fires a Member of the Nuclear Regulatory Commission*, NPR (June 16, 2025, 12:30 PM), https://www.npr.org/2025/06/16/nx-s1-5435285/trump-fires-nuclear-regulatory-commission-member-nrc [https://perma.cc/F57G-QHZL]. Hanson's removal came via email notification from the White House. *Id.* While no official reason has been made public at this time, White House Deputy Press Secretary Anna Kelly told National Public Radio, "All organizations are more effective when leaders are rowing in the same direction" and that "President Trump reserves the right to remove employees within his own Executive Branch who exert his executive authority." *Id.*

Moreover, NRC staff reductions are unsound public policy and defy logic if revitalization of the nuclear industry is a national priority. The reductions contravene the ADVANCE Act provisions authorizing the hire of many additional highly qualified NRC scientists and staff. Congress clearly recognized that more staff, not less, would be needed to achieve the goal of expeditious review of nuclear licenses without sacrificing safety.[328]

Finally, the Order emphasizes that NRC is also to consider the economic and national security benefits of nuclear power when licensing nuclear reactors, "in addition to safety, health, and environmental considerations."[329] In light of the President's recent order abolishing all Council on Environmental Quality regulations governing the federal government's compliance with NEPA, the provisions directing NRC and DOE to reconsider NEPA requirements for nuclear facilities[330] sounded an alarm, even though the ADVANCE Act authorized warranted and sensible reforms to NEPA's implementation at NRC.[331]

While the Order maintains that all the actions required will be based upon sound science, protect safety, and be performed in accordance with law,[332] that assurance appeared hollow when viewed through the lens of the damaging changes to NRC's independence and its safety regulations The assurance indeed proved to be hollow when DOE published its recent notice, concerning NEPA rulemakings, which signals that DOE supports changes that go well beyond the reasonable reforms dictated by the ADVANCE Act.[333]

Executive Order 4299 also highlights the difference between the Republicans' and Democrats' policy reasons for supporting nuclear power.

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328. *See* ADVANCE Act § 402.

329. *See* Exec. Order 14300, *supra* note 314, § 3, at 22588. Caution signals on the environmental front are broadcast most strongly by the executive mandates that DOE and NRC management and regulations be streamlined immediately, requesting even more reform to the environmental impact review process than already detailed in the ADVANCE Act.

330. *See id.* § 5(c), at 22589; Exec. Order 14301, *supra* note 314, § 6, at 22592–93.

331. *See supra* Section IV.C. President Trump's documented environmental record during his first term is also cause to be wary of further reductions in ESH protections. *See* Nadja Popovich, Livia Albech-Ripka & Kendra Pierre-Louis, *The Trump Administration Is Reversing Nearly 100 Environmental Rules*, HARV. U. CTR. FOR ENV'T (Oct. 15, 2020), https://www.environment.harvard.edu/news/trump-administration-reversing-nearly-100-environmental-rules [https://perma.cc/R32B-KM7U].

332. *See* Exec. Order 14300, *supra* note 314, § 5(b)–(i), at 22589.

333. *See generally* Revision of National Environmental Policy Act Implementing Procedures, 90 Fed. Reg, 29676 (July 3, 2025) (DOE's interim final NEPA rules move many former mandatory rules to "procedural guidance."). The Supreme Court also recently upheld an agency's refusal to assess "indirect effects" of a rail corridor under NEPA. *See* Seven Cnty. Infrastructure Coal. v. Eagle County, 145 S. Ct. 1497 (2025). That decision signals that challenges to NEPA regulatory revisions in court will face an uphill battle. So far, NRC efforts in revising its NEPA rules appear consistent with the ADVANCE Act. *See* Memorandum from Carrie M. Safford, Secretary, NRC, to Michael F. King, Acting Exec. Dir. for Operations, NRC, Staff Requirements – SECY-24-0046 – Implementation of the Fiscal Responsibility Act of 2023 National Environmental Policy Act Amendments (July 28, 2025), https://www.nrc.gov/docs/ML2520/ML25209A050.pdf [https://perma.cc/R6ML-6SX4].

The current Administration supports the expansion of energy from fossil fuels as well as nuclear power, but has drastically cut federal funding for wind, solar, and other alternative energy projects.[334] The President sees expanding nuclear power as a tool for energy independence, national security, industrial development, and meeting increasing demand for energy by the private sector.[335] On the other hand, President Biden and many Democrats now support nuclear power as a clean energy source that will both meet increasing demand and reduce reliance on fossil fuels in combating global warming and climate change.[336]

On the positive side, other provisions of the executive orders are consistent with the ADVANCE Act's statutory framework analyzed previously. For example, among the more important mandates of Executive Order 14302 are the following initiatives designed to immediately reinvigorate the nuclear industrial base. DOE is to take the following actions: (1) provide additional financial incentives for the private construction of ten new large-scale reactors, as well as five gigawatts of power uprates to existing nuclear reactors, with construction beginning no later than 2030; (2) develop a plan to increase domestic uranium conversion and enrichment capacity, in consultation with the NRC and the Office of Management and Budget ("OMB"), by September 20, 2025; and (3) establish a program to process excess plutonium held by the National Nuclear Security Administration into a form that can be used in advanced nuclear reactors.[337]

DOE is also required to pursue agreements with private companies to supply low-enriched uranium ("LEU") and high-assay low-enriched uranium ("HALEU") to jump-start the construction of SMRs which require such fuel.[338] As analyzed previously, advanced SMRs are capable of breeding usable fuel while they are producing energy.

Addressing the nuclear waste problem, DOE is to coordinate with the Department of Defense ("DOD"), Department of Transportation ("DOT"), and OMB, and then submit a report to the President by January 18, 2026 that includes analysis and recommendations on the spent nuclear fuel issue, including management of nuclear fuel recycling.[339] Executive Order 14299 requires DOE to identify all U.S. uranium and plutonium stockpiles that may be recycled into new fuel within ninety days of the order.[340] DOE is also

334. *See* OFF. OF MGMT. & BUDGET, EXEC. OFF. OF THE PRESIDENT, FISCAL YEAR 2026 DISCRETIONARY BUDGET REQUEST 30 (May 2, 2025), https://www.whitehouse.gov/wp-content/uploads/2025/05/Fiscal-Year-2026-Discretionary-Budget-Request.pdf [https://perma.cc/HJ56-MCDW].

335. *See* Exec. Order 14299, *supra* note 314, § 1, at 14299.

336. *See supra* text accompanying note 277.

337. Exec. Order 14302, *supra* note 314, §§ 3(b)–(c), 4(a)–(c), at 22596–97.

338. *Id.* § 3(e)–(h), at 22596–97.

339. *Id.* § 3(a)(i)–(ix), at 22595–96.

340. Exec. Order 14299, *supra* note 314, § 5(a), at 22582.

authorized to construct a fuel recycling facility at a DOD or DOE site using all legal means.[341] These provisions implement the ADVANCE Act and are a major break in the stalemate over SNF storage and disposal. This Article previously noted that construction of nuclear waste storage, recycling, or reprocessing facilities in the United States at existing military or DOE nuclear facilities is one way to avoid the NIMBY problem often encountered by the private sector in obtaining approval for the siting of such plants.[342] Since DOE will at last take possession of the spent fuel as required by the NWPA, any action by DOE on federal nuclear sites to "dispose" of the materials by recycling or reprocessing should be considered legal so long as applicable ESH requirements are met. To expedite advanced reactor testing, DOE is directed by Executive Order 14301 to establish a new test reactor pilot program and to streamline DOE regulations to enable rapid deployment of test reactors at DOE and national laboratory sites. The goal of this order is construction of at least three new nuclear reactors and achievement of criticality by July 4, 2026.[343] DOE is also ordered to expedite this deployment of advanced reactors at DOE and national laboratory sites by revising DOE regulations and streamlining procedures by August 21, 2025 to allow the test reactors to be operational within two years.[344] Since the nuclear test reactor program has been a part of DOE's responsibility since the enactment of the AEA, and modernization of the program is already underway, this order is a positive development so long as expediency does not override safety at DOE installations.

Executive Order 14299, entitled "Deploying Advanced Nuclear Reactor Technologies for National Security," mandates the rapid testing, licensing, and deployment of those technologies at federal facilities.[345] For example, DOE must designate one or more sites for the deployment of advanced reactors, provided they are owned or controlled by the DOE, within 90 days of the date of the executive order "for the purpose of powering AI infrastructure," and with the goal of operating an advanced reactor by November 23, 2027.[346] Similarly, the United States Army must establish a program to operate a nuclear reactor "at a domestic military base or installation no later than September 30, 2028,"[347] thus avoiding the NIMBY problem while supplying needed energy to military bases.

While many of the initiatives ordered on May 23, 2025 are fully consistent with the ADVANCE Act and the policy recommendations of this Article, caution is warranted because some of the mandates could subordinate safety to economics and the President's other priorities. The extremely ambitious goals

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341. *Id.* § 5(c), at 22583.
342. *See supra* text accompanying note 223.
343. Exec. Order 14301, *supra* note 314, § 5(a), at 22592.
344. *Id.* § 4(b), at 22592.
345. Exec. Order 14299, *supra* note 314, § 2(a)–(c), at 22581.
346. *Id.* § 4(b)–(c), at 22582.
347. *Id.* § 3(a), at 22581–82.

and deadlines established by the orders clearly signal that this Administration is committed to rapid licensing and deployment of the technologies supported by the ADVANCE Act. Those goals and deadlines should not signal a retreat from the preeminence of safety required by the AEA and current NRC regulations.

While the executive orders demonstrate that bipartisan support for nuclear revitalization is continuing, albeit for different policy reasons, some of mandates in the orders raise a red flag. Nuclear power can and should expand rapidly, but not at the cost of safety. Nuclear revitalization requires scientifically sound safety regulations and more staff at both DOE and NRC, not fewer, if the revitalization effort is to move forward rapidly and safely with support from both political parties.

CONCLUSION

No method of providing electric energy is without risk. Since the TMI accident, the nuclear power industry has continued to produce major ESH advances while also making reactor technology better, safer, and more efficient. The scientific data show that nuclear power is one of the cleanest *and* safest sources of energy per terawatt hour. The potential residual risk of radiation releases from licensed nuclear facilities has been minimized by technology and sound regulation.

The very low risk of radiation releases must be balanced against the known risks of continuing to use fossil fuels to meet our energy needs. For example, fossil fuels currently cause the most deaths per terawatt hour, as coal (24.62) and oil (18.43) are significantly more deadly than wind (0.04), nuclear (0.03), and solar (0.02).[348] Petroleum-based power causes cancer, disease, and deaths during the entire production cycle from the extraction, to processing, to subsequent use as fossil fuel.[349] The fossil fuel production and use cycle causes extensive damage to the environment, most notably the release of greenhouse gases responsible for global warming and climate change, in addition to public health harms.[350]

The political climate is such that facts are often disregarded or distorted in public policy debate. Nevertheless, despite public perception, the U.S. nuclear power industry's record of compliance with EPA and NRC's basic environmental, safety, and health requirements has been extraordinary, even considering the TMI accident. Many environmental groups, long-term skeptics of nuclear power, have reviewed that safety record and now are advocates

348. Hannah Ritchie, *What Are the Safest and Cleanest Sources of Energy?*, OUR WORLD IN DATA (Feb. 10, 2020), https://ourworldindata.org/safest-sources-of-energy [https://perma.cc/QC9K-LEEU]; Benjamin K. Sovacool et al., *Balancing Safety with Sustainability: Assessing the Risk of Accidents for Modern Low-Carbon Energy Systems*, 112 J. CLEANER PROD. 3952, 3956 (2016).

349. *See* Ritchie, *supra* note 348.

350. J. Lelieveld et al., *Effects of Fossil Fuel and Total Anthropogenic Emission Removal on Public Health and Climate*, 116 PROC. NAT'L ACAD. SCIS. 7192, 7192 (2019).

of nuclear power as a means of combating global warming.[351] Even the international community, which was slow to accept nuclear technology as a means for reducing greenhouse gas emissions, has reversed previous policy against the nuclear option: During the 2023 Conference of Parties (COP 28) in Dubai, the United Nations' treaty parties on climate change pledged to triple their nuclear energy outputs by 2050, recognizing for the first time the importance of nuclear power as a clean energy source.[352]

The safety concerns often expressed by opponents to nuclear power in the past should not stall the revitalization triggered by the ADVANCE Act and prior legislation. Nuclear power should have a leading role in both meeting rising energy demand and combating global warming. The first wave of the next generation of large-scale nuclear reactors with enhanced passive safety systems has already been licensed in the United States, China, and elsewhere, with more scheduled to be brought online soon. Smaller-scale SMR plants are already being tested and built as well. Moreover, nuclear waste reprocessing and recycling offers a technologically manageable solution to our nuclear waste storage and disposal problems. Bipartisan political assessment of those advances, together with the nuclear safety record in democratic nations around the world, resulted in the legislative initiatives analyzed in this Article. Those legislative initiatives will continue to accelerate advancements in nuclear energy production, fuel reprocessing, and storage.

To ensure that the nuclear waste issue does not stall the push for more nuclear power plants, Congress should immediately pass amendments to the NWPA clarifying NRC's existing authority to license both private consolidated interim storage and DOE-monitored retrievable storage facilities, with appropriate ESH restrictions and incentives to overcome opposition by state and local officials.[353] Such storage allows existing plants to continue to operate while legislative efforts to restore reprocessing in the United States bear fruit.

Other nations recognize reprocessing as the most efficient and environmentally sound method of dealing with valuable nuclear materials. Experts believe that even without ongoing advancements in waste technology, current reprocessing methods adapted for use in the United States can obviate

351. *See* Amy Harder, *Environmental Group: Keep Open Nuclear Power Plants*, AXIOS (Nov. 8, 2018), https://www.axios.com/2018/11/08/environmental-group-keep-open-nuclear-power-plants [https://perma.cc/6M8N-KJPL] ("[T]he Union of Concerned Scientists . . . . [who] ha[d] been one of the most vocal critics of the industry about safety" now supports keeping existing power plants open); Uri Berliner, *Why Even Environmentalists Are Supporting Nuclear Power Today*, NPR (Aug. 30, 2022, 1:34 PM), https://www.npr.org/2022/08/30/1119904819/nuclear-power-environmentalists-california-germany-japan [https://perma.cc/E8G7-SXJG].

352. *At COP28, Countries Launch Declaration to Triple Nuclear Energy by 2050, Recognizing the Key Role of Nuclear Energy in Reaching Net Zero*, U.S. DEP'T ENERGY (Dec. 1, 2023), https://www.energy.gov/articles/cop28-countries-launch-declaration-triple-nuclear-energy-capacity-2050-recognizing-key [https://perma.cc/VHZ9-76N4].

353. The conditions and incentives for locating such facilities have been described above. *See supra* Part III.

the need for a geological repository and ultimately reduce or eliminate uranium mining. Therefore, congressional amendments to the NWPA should explicitly support DOE and private reprocessing of nuclear fuel, ending the ill-advised ban on this economically and environmentally sound method of turning waste into useable nuclear materials.

Even with the private sector improvements in technology and more flexible and effective NRC regulatory systems, nuclear power plants must be built with the utmost attention to safety. A single major accident in the United States would almost certainly halt the hard-earned progress made so far. With those legitimate safety concerns in mind, nuclear power can and should take the lead in combatting global warming while also meeting massive increases in energy demand here and abroad. Other forms of alternative energy such as wind and solar should continue to be part of an "all of the above" effort to meet international commitments designed to combat global warming.

So long as the Executive Branch does not become overzealous in their pursuit of more nuclear power plants at any cost to the environment or public health, increased reliance on nuclear power to gain energy independence and to meet climate change commitments is sound policy. This can be accomplished by continuing to implement recent laws, especially the ADVANCE Act, and policies that reinforce the commitment to safe operations of nuclear facilities, while stimulating technological strides that make nuclear power more widespread and efficient.