CONSIDERING THE PRICE-ANDERSON ACT'S FEDERAL PUBLIC LIABILITY ACTION PROVISIONS IN THE FUTURE OF NUCLEAR FUSION POWER

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Fusion power technology has seen rapid development in the past decade. Although its promise of nearly-infinite, carbon-free electricity still has years to go in development to reach true commercialization, the Nuclear Regulatory Commission (NRC) is already working to incorporate fusion technologies in its modernized regulatory scheme by a 2027 Congressional mandate, and fusion development companies hope to bring their prototypes online within the next decade. Although there has been considerable attention to how fusion plants may fit in the various provisions of the Atomic Energy Act (AEA), existing NRC regulations, and the insurance provisions of the Price-Anderson Act (PAA) (which provide the central underwriting of America's nuclear power industry), less attention has been paid to how fusion plants fit under the other major part of the PAA—those provisions providing for an exclusively federal cause of action and limitations on liability in the wake of a "nuclear incident." Surveying current case law and undertaking an in-depth definitional analysis, this Article explores how key provisions of the PAA public liability framework may apply to a hypothetical fusion accident and suggests that there are unresolved ambiguities which may be problematic should an incident arise. The current climate of change in nuclear regulation and policy provides

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a natural and convenient point for resolving these ambiguities proactively before an incident occurs.

INTRODUCTION

The December 2022 success of the National Ignition Facility (NIF) in achieving net-positive energy gain in a fusion reaction reignited public interest in the possibility of fusion power.[1] Less than one month later, the staff of the Nuclear Regulatory Commission (NRC) recommended the start of new rulemaking for fusion systems rather than forcing a fit into existing regulatory options. Just three months later, the NRC itself voted for the regulation of fusion systems under existing rules instead of pursuing new rulemaking.[2] Although the practical use of fusion power remains decades of development away,[3] the NIF breakthrough nonetheless represents a significant step forward, and it serves as another illustration of just how far nuclear power has come. In just over seventy years, nuclear power has advanced from powering a single light bulb to providing thousands of terawatts of carbon-free energy around the globe.[4] As the need for carbon-free power becomes increasingly urgent in the wake of climate change, there has been a resurgence of interest in nuclear power technologies from across the political spectrum.[5]

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[1] Daniel Clery, *With Historic Explosion, a Long Sought Fusion Breakthrough*, SCI. NEWS (Dec. 13, 2022, 10:00 AM), https://www.science.org/content/article/historic-explosion-long-sought-fusion-breakthrough [https://perma.cc/JJR8-Q66D]; *see* Umair Irfan, *We Have a Genuine Fusion Energy Breakthrough*, VOX (Dec. 13, 2022, 10:45 AM), https://www.vox.com/recode/23505995/fusion-energy-breakthrough-announcement-ignition-nif [https://perma.cc/YW5X-72HZ].

[2] Memorandum from Daniel H. Dorman, Exec. Dir. of Operations, NRC, to the Commissioners, SECY-23-0001 Options for Licensing and Regulating Fusion Energy Systems (Jan. 3, 2023), https://www.nrc.gov/docs/ML2227/ML22273A163.pdf [hereinafter NRC FUSION MEMORANDUM] [https://perma.cc/WBH2-ZS6J]; Memorandum from Brooke P. Clark, Sec'y, NRC, to Daniel H. Dorman, Exec. Dir. of Operations, NRC, Staff Requirements – SECY-23-0001 – Options for Licensing and Regulating Fusion Energy Systems (Apr. 13, 2023), https://www.nrc.gov/docs/ML2310/ML23103A449.pdf [hereinafter NRC FUSION DECISION] [https://perma.cc/ME74-EYT9].

[3] *See* Clery, *supra* note 1.

[4] *See* U.S. DEP'T OF ENERGY, THE HISTORY OF NUCLEAR ENERGY 9 (2002); *Nuclear Power in the World Today,* WORLD NUCLEAR ASS'N, https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx (Aug. 2023) [https://perma.cc/9LBD-YC8V].

[5] *See, e.g.*, Energy Act of 2020, Pub. L. 116-260 Div. Z §§ 2001–2008, 116th Cong. (2021) (detailing extensive Congressional support on the order of billions of dollars for such programs as advanced fuel development, demonstration projects for advanced nuclear reactors, and development of fusion power plants in a bipartisan bill); Nuclear

Yet as history has shown, even the most ardent supporter of nuclear technologies cannot deny that they present risk. So too, would be the case for new nuclear technologies, whose risks are less defined given the novelty of the technologies and the sheer diversity of concepts under development.[6] Even if an incident at a nuclear power plant does not directly cause any casualties, the resultant injury claims from a single incident can be in the thousands.[7]

Even before any major nuclear incident occurred, Congress identified this sort of potential runaway liability as posing a risk of not only being impossible to resolve for the good of the public, but of disincentivizing entry into the nuclear power space outright.[8] In response, in 1957 Congress amended the still-nascent Atomic Energy Act of 1954 with the Price-Anderson Act (PAA).[9] The PAA established the primary insurance and financial indemnification mechanism for NRC licensees and Department of Energy (DOE) contractors working with nuclear material.[10]

At its core, the PAA provides for indemnification against damages arising from a "nuclear incident,"[11] requiring licensees and contractors to enter into a national insurance scheme, and establishing limits on total public liability arising from such an incident.[12] The most significant set of amendments, the Price-Anderson Amendments Act of 1988, created a specific federal public

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Energy Innovation and Modernization Act, Pub. L. 115-439, 115th Cong. (2019) (expressly calling for the "develop[ment] of the expertise and regulatory processes necessary to allow innovation and commercialization of advanced nuclear reactors").

[6] *See, e.g.*, Office of Nuclear Energy, *Advanced Reactor Technologies,* U.S. DEP'T OF ENERGY, https://www.energy.gov/ne/advanced-reactor-technologies (last visited Nov. 22, 2023) (describing the broad range of technologies under the "advanced reactor" umbrella, from small modular reactors to large plants that provide both electricity and industrial process heat) [https://perma.cc/4W54-SPF6].

[7] *See, e.g.*, *In re* TMI Litigation, 193 F.3d 613, 623 (3d Cir. 1999).

[8] H. ARCENEAUX ET AL., NUCLEAR REGUL. COMM'N, THE PRICE-ANDERSON ACT: 2021 REPORT TO CONGRESS xvi (2021).

[9] *Id.*

[10] Price-Anderson Act of 1957, Pub. L. 85-256 (1957) (codified as amended in 42 U.S.C. §§ 2014, 2210).

[11] *Id.*

[12] 42 U.S.C. §2210(c)–(d), (e) (1957).

liability action for claims brought under the PAA.[13] Courts have since routinely held that many state claims brought alongside any PAA claim are preempted.[14] Initially enacted on a limited-time basis in 1957 with a focus on the "atomic energy industry,"[15] the PAA has been extended several times and has seen its provisions expanded and brought to court for non-nuclear-plant operators, such as landfills and universities.[16] The Energy Policy Act of 2005 further extended the PAA indemnification provisions to 2025, requiring reports from the NRC and DOE to help determine whether to extend the provisions beyond 2025.[17]

Despite its longevity, the PAA's provisions were nonetheless written against the backdrop of the dawn of nuclear power. Even after extensive subsequent amendments in the six decades since its enactment, the language of the PAA remains couched in the risks known to the nuclear community during the age of fission-based power. As such, while its verbiage clearly applies to modern nuclear power plants, it is less obvious how its provisions might apply to the more exotic and novel nuclear power plants of the future. In particular, fusion power plants, which operate with entirely different fuels and fundamental physics than fission power plants, do not fit squarely into many of the crucial definitions of the PAA.[18] Although fusion power is touted for its possible safety improvements over fission-based plants, the technology is nonetheless unproven, and it has engineering requirements often associated with inherent risk, such as high temperatures, pressures, and magnetic fields.

This paper focuses on how some of the most essential definitions and elements of the PAA might apply to future fusion power plants—in particular, how fusion power

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[13] Price-Anderson Amendments Act of 1988, Pub. L. No. 100–408 (1988) (codified at 42 U.S.C. § 11(b)).

[14] *See, e.g.*, Cook v. Rockwell Int'l Corp., 618 F.3d 1127, 1142–44 (10th Cir. 2010).

[15] Pub. L. 85-256 § 1 (codified at 42 U.S.C. § 2012(i)).

[16] *See, e.g.*, Strong v. Republic Servs., Inc., 283 F. Supp. 3d 759 (E.D. Mo. 2017); Estate of Ware v. Hosp. of the Univ. of Penn., 871 F.3d 273 (3d Cir. 2017).

[17] Energy Policy Act of 2005, Pub. L. 109-58, § 602 (2005) (codified at 42 U.S.C. § 2210(c)).

[18] *See* discussion *infra* Part IV.

plants may or should be captured by the provisions governing the PAA's federal public liability cause of action. Part II presents a brief overview of how fusion technologies differ from fission technologies, as well as providing an overview of the PAA. Part III examines the most significant provisions of the PAA that are typically contested, as well as examining the modern jurisprudence surrounding these provisions. Part IV applies these provisions and modern law to the expected implementations of fusion power, using a brief case study in the form of a hypothetical fusion power accident, and discusses how current efforts in nuclear regulation could be used to resolve ambiguities in the resultant PAA public liability analysis. Part V briefly concludes.

I. A BRIEF OVERVIEW OF NUCLEAR POWER TECHNOLOGIES AND THE PRICE-ANDERSON ACT

Before considering how the PAA might apply to fusion power plants, it is important to understand how fusion power technologies differ from existing fission power technologies, as well as understanding how the PAA operates. A brief overview of both of these topics is described herein.

A. The Science of Fusion and Fission

All nuclear power plants in operation today make use of nuclear fission—the splitting of an atom—to generate energy. In a normal stable nucleus, the positively-charged protons and neutrally-charged neutrons—collectively referred to as nucleons—are held together by the fundamental "nuclear" (or "residual strong") force.[19] This force overcomes the repulsive force of the positively-charged protons to each other.[20] The nuclear force,

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[19] 1 U.S. DEP'T OF ENERGY, DOE FUNDAMENTALS HANDBOOK: NUCLEAR PHYSICS AND REACTOR THEORY 9 (1993), https://www.standards.doe.gov/standards-documents/1000/1019-bhdbk-1993-v1/@@images/file [hereinafter DOE HANDBOOK] [https://perma.cc/7QMV-W6FW].

[20] *Id.* at 49.

although strong, acts only on a short distance (on the order of 10^{-13} centimeters).[21]

It is a physical fact that the mass of a given nucleus with a known number of nucleons is less than the mass of the sum of the individual nucleons.[22] The difference is known as the mass defect, and it comes from mass being converted to energy that binds the nucleus together via $E = mc^2$.[23] The expression of mass defect in terms of energy is known as binding energy, and can be alternatively conceptualized as the amount of energy required to separate the nucleus into its constituent nucleons.[24] The binding energy is dependent upon the mass number of the nucleus; that is, the total number of nucleons.[25] The energy released by any given nuclear reaction—either fission or fusion—is thus determined by the total binding energy of the reacting particles.[26] Figure 1 shows the binding energy *per nucleon* versus the atomic mass of a given nucleus.[27]

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[21] *Id.* at 9.

[22] JOHN R. LAMARSH & ANTHONY J. BARATTA, INTRODUCTION TO NUCLEAR ENGINEERING 31 (Marcia J. Horton et al. eds., 4th ed. 2014).

[23] *Id.* at 30.

[24] *Id.*

[25] *Id.* at 31.

[26] *Id.* at 32.

[27] In nuclear physics and engineering, energy is typically expressed in electron volts (eV). 1 eV equals 1.602×10^{-19} joules. The most common expression of eV is the megaelectron volt (MeV), equal to one million eV; also common is the kiloelectron volt (keV), equal to 1000 eV.

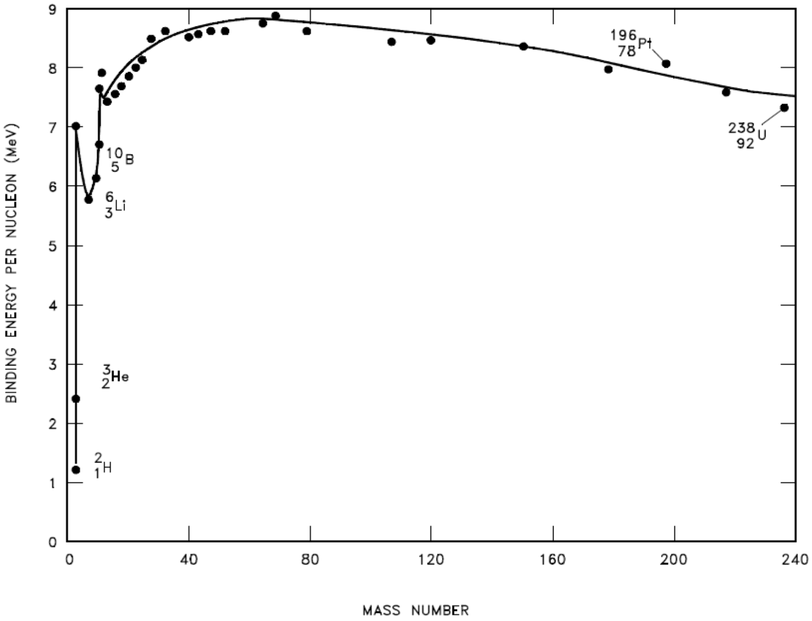

Figure 1: Binding Energy Per Nucleon vs. Atomic Mass Number[28]

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[28] DOE HANDBOOK, *supra* note 19, at 53.

The higher the binding energy, the more stable the nuclide, with the most stable nuclides existing at mass number 56, the peak of the curve in Figure 1.[29] If the total binding energy of a "more stable" nuclide exceeds that of an initial nuclide, the differential amount of energy must be released.[30] Both nuclear fission and nuclear fusion technologies make use of this released energy, which is in the form of kinetic energy of the reaction products.[31] Fission is the process by which nuclides *split* to produce products with higher binding energy per nucleon—moving leftward from the far right side of Figure 1, towards the stability peak—while fusion is the process by which nuclides *merge* to produce products with higher binding energy per nucleon—moving rightward towards the peak from the left.[32]

In a fission reaction, a neutron strikes a stable nucleus. For a fraction of a second, the neutron and the nucleus exist as one single energized entity known as a compound nucleus.[33] If enough energy is present in the compound nucleus, it becomes deformed.[34] If this deformation is large enough, parts of the nucleus can drift far enough apart such that the short-ranged nuclear force is not enough to counteract the repulsive force of the positively-charged parts towards each other.[35] If that occurs, the nucleus will split, and the resulting smaller daughter products will thus move left on the curve, towards higher binding energy per nucleon and greater stability.[36] This results in the overall higher total binding energy of the daughter products; the difference of their total binding energy from that of the original nucleus is the amount of energy that is released.[37]

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[29] *Id.* at 14, 57.
[30] *Id.* at 57.
[31] *Id.* at 60.
[32] *Id.* at 54.
[33] *Id.* at 48.
[34] DOE HANDBOOK, *supra* note 19, at 49–50.
[35] *Id.* at 49.
[36] *Id.* at 53–54.
[37] *Id.* at 57.

A single atom of uranium-235, ${}^{235}_{92}\mathrm{U}$,[38] has a binding energy of 7.591 MeV per nucleon or (235)*(7.591 MeV) = 1783.9 MeV of total binding energy.[39] In a fission of one uranium-235 nucleus, one neutron, ${}^{1}_{0}\mathrm{n}$, reacts with the uranium nucleus to generate three free neutrons, a cesium-140 (${}^{140}_{55}\mathrm{Cs}$) and a rubidium-93 (${}^{93}_{37}\mathrm{Rb}$) nucleus.[40] Cesium-140 and rubidium-93 have binding energies per nucleon of 8.314 MeV and 8.541 MeV, respectively, resulting in total binding energies of 1163.96 MeV and 794.31 MeV, respectively.[41] The energy difference from the original uranium nucleus and its daughter products is thus (1163.96 + 794.31) - 1783.9 = 174.37 MeV, or 2.794×10^{-11} joules. This is the amount of energy released in the fission of a *single* uranium atom. Considering that a kilogram of uranium has roughly 2.53×10^{24} atoms of uranium,[42] this would amount to 8.2×10^{7} megajoules per kilogram. Compare that value to the energy released from a kilogram of coal—a mere 25 megajoules per kilogram.[43]

Fusion involves the far-left side of the peak in Figure 1, where it can be observed that the binding energy per nucleon becomes greater as the atomic mass number increases. The National Ignition Facility's (NIF) ignition in 2022 fused together one tritium atom (triton), ${}^{3}_{1}\mathrm{H}$, which has a binding energy per nucleon of 2.827 MeV, and one deuterium atom (deuteron), ${}^{2}_{1}\mathrm{H}$, which has a binding energy per nucleon of 1.112 MeV.[44] The fusion reaction results in

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[38] The upper number in this notation represents the mass number (the total number of nucleons), while the bottom number represents the atomic number (the number of protons, which determines the element). Atoms of a given element—with the same atomic number—which have different mass numbers are known as isotopes.

[39] *Live Chart of Nuclides,* INT'L ATOMIC ENERGY AGENCY, https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html (last visited Nov. 22, 2023) [hereinafter *Nuclides Chart*] [https://perma.cc/8SNB-QUK4].

[40] DOE HANDBOOK, *supra* note 19, at 59.

[41] *Nuclides Chart*, *supra* note 39.

[42] *See* LAMARSH & BARATTA, *supra* note 22, at 754 (Uranium has a nominal density of 19.1 g/cm^3 and $.04833 \times 10^{24}$ atoms/cm^3, yielding 3.95×10^{-22} g/atom, or 2.53×10^{21} atoms/g. With 1000 g/kg, there are thus 2.53×10^{24} atoms/kg).

[43] *Heat Values of Various Fuels,* WORLD NUCLEAR ASS'N, https://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx (last visited Nov. 22, 2023) [https://perma.cc/FSW5-MVGU].

[44] Lawrence Livermore Nat'l Lab'y, *How NIF Works,* NAT'L IGNITION FACILITY & PHOTON SCI., https://lasers.llnl.gov/about/how-nif-works (last visited Nov. 22, 2023) [https://perma.cc/Y3GV-NFDG]; *Nuclides Chart*, *supra* note 39.

a free neutron and a single helium atom ($^{4}_{2}He$) which has a binding energy per nucleon of 7.074 MeV.[45] The energy release is thus (7.074*4) – (2.827*3 + 1.112*2) = 17.591 MeV or 2.818 x 10^{-12} joules per single reaction.

The energy in these nuclear reactions comes from the conversion of mass to energy—recall that binding energy is an alternative presentation of mass defect. Using the above reaction as an example, tritium has a mass of 3.016 amu,[46] deuterium a mass of 2.014 amu, a neutron a mass of 1.0087 amu, and a helium atom a mass of 4.0026 amu.[47] The mass defect is thus (3.016 + 2.014) + (1.0087 + 4.0026) = .0187 amu. Converting this to energy via $E = mc^2$ yields E = (.0187 amu * 1.66057 x 10^{-27} amu/kg) * (2.998 x 10^8 m/s)^2 = 2.791 x 10^{-12} joules, an equivalent result to the same calculation done using binding energies.[48]

While 17.5 MeV is much less than 174 MeV per reaction, when considered in terms of energy released per unit mass, the difference is staggering. Uranium-235 is almost 50 times as massive as a triton and a deuteron together, but using even the rudimentary calculations above, only ten reactions between a triton and a deuteron are needed to react to release the same amount of energy. These ten fusion reactions thus require less than a third of the total mass required to produce the same amount of energy from a single uranium fission, representing a tremendous improvement in energy production efficiency. The difference between uranium as a fuel and coal as a fuel was already significant enough; it is apparent how an operating fusion plant, especially given the relatively easy access to hydrogen as a fuel compared to uranium, would revolutionize energy production.

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[45] *Nuclides Chart*, *supra* note 39.

[46] *See* LAMARSH & BARATTA, *supra* note 22, at 10–11 (Atomic mass units (amu) are a standardized unit used to describe the mass of nuclei and nucleons, where 1 amu = 1/12 the mass of a single carbon-12 atom, or 1.66057 x 10^{-27} kg).

[47] *Nuclides Chart*, *supra* note 39.

[48] The example here used some rounding for simplicity and is the source of this error. Using more exact values for binding energies and mass yields a more precise result.

B. Differences Between Fission and (Theorized) Fusion Power Plants

Fission nuclear power plants harness this released energy through chain reactions of fissioning heavy nucleons—more specifically, particular isotopes of uranium and plutonium, on the far right side of the peak in Figure 1.[49] When fissionable nuclei break, the reaction generates not only smaller daughter nuclei, but free neutrons.[50] These neutrons can then be used to drive another fission reaction, which generates additional neutrons for another generation of reactions, and so on.[51] When the number of fissions in one generation equals the number of fissions in the subsequent generation, the reactor is deemed "critical."[52] If fewer fissions occur in the subsequent generation than the first generation, the reactor is subcritical; if more fissions occur in the subsequent generation than the first generation, the reactor is supercritical.[53] The kinetic energy of the daughter products is imparted to coolant as heat, which in turn goes through a series of heat exchanges to generate electricity via steam-powered turbines.[54]

The most significant safety concern in fission power plants is the containment of radioactive material. Radioactive material includes not only the fuel itself, but the radioactive daughter products as well. Two of the major nuclear power plant accidents to date—Three Mile Island in 1979 and Fukushima in 2011—both suffered containment failures due most directly to a loss of coolant to the core.[55] Without means to transfer either the fission-generated heat or the latent heat of decay away from the

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[49] LAMARSH & BARATTA, *supra* note 22, at 122–23.

[50] *Id.* at 120.

[51] *Id.*

[52] *Id.*

[53] *Id.*

[54] *Id.* at 139.

[55] LAMARSH & BARATTA, *supra* note 22, at 698, 704; *Fukushima Daiichi Accident*, WORLD NUCLEAR ASS'N, https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-daiichi-accident.aspx (Aug. 2023) [https://perma.cc/WQP9-ELVV].

fuel, the fuel will begin to melt inside the reactor vessel.[56] As the fuel continues to generate heat, it can lead to exothermic chemical reactions which can generate hydrogen, creating a high risk of explosion, and can breach its containment vessel.[57]

If the reactor is otherwise able to go supercritical, reactor power can climb extremely rapidly as the reactor enters a positive feedback loop.[58] If such a power spike is rapid enough, the reaction can become uncontrollable, which may lead to overheating and a coolant explosion if the coolant is unable to receive the excess of heat.[59] This was the (simplified) cause of the 1986 Chernobyl disaster, where such a supercritical state was reached when water, which absorbed neutrons, was displaced by graphite, which slowed the neutrons to energies more likely to produce fission, in a rapid attempt to shut down the reactor.[60] The power spike caused a steam explosion which totally destroyed the reactor containment vessel and grossly contaminated the surrounding environment.[61]

Fission reactors also generate spent fuel waste, in the form of depleted uranium and its radioactive daughter products.[62] Daughter products, however, only constitute a small fraction of long-lived fission waste, and thus reprocessing of spent uranium and plutonium fuel can greatly reduce the long-lived waste that must be otherwise stored.[63]

In contrast, fusion reactors operate on the left side of the binding energy curve in Figure 1, and thus use light nucleons as fuel. In today's fusion research reactors, the deuterium (^2_1H) and tritium (^3_1H) fusion described above is

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[56] LAMARSH & BARATTA, *supra* note 22, at 693–94.

[57] *Id.*

[58] *See id.* at 121 (The feedback loop is "positive" because more fissions in each generation generate more neutrons, which in turn cause even *more* fissions in the next generation, resulting in an exponentially growing rate of fission reactions if left uncontrolled).

[59] *See, e.g.*, *id.* at 700.

[60] *Id.*

[61] *Id.* at 701–03.

[62] LAMARSH & BARATTA, *supra* note 22, at 224.

[63] *Id.*

the reaction most commonly used.[64] Unlike fission, however, the reaction is not readily sustainable at atmospheric pressures and temperatures. The electrostatic repulsion between two such positively-charged nuclei cannot be overcome absent an initial insertion of energy and forced density to allow the short-acting strong nuclear force to overcome the electrostatic force.[65] These conditions occur naturally in stars, which have both extremely high temperatures and gravitational forces, but on Earth, the technological challenge in replicating such conditions is enormous.[66]

The technologies being researched to create the conditions for a sustained fusion reaction can be placed into two broad categories: magnetic confinement and inertial confinement.[67] In magnetic confinement designs, the fuel is superheated to a plasma, which allows the atoms to dissociate into ions.[68] Since these ions are charged, they follow magnetic fields. Magnetic confinement technologies generate magnetic fields designed to keep the density of the plasma high enough for fusion to occur.[69] In some designs, the resultant current in the plasma itself generates enough heat for fusion; in others, additional heat must be supplied.[70]

In inertial confinement designs, such as the NIF, a small fusion fuel pellet is forcibly imploded when its outer shell is superheated by lasers.[71] The fuel within the pellet is thus immediately compressed to densities that are conducive to fusion.[72] The energy released by these internal

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[64] P.K. KAW & I. BANDYOPADHYAY, *The Case for Fusion, in* FUSION PHYSICS 1, 20 (Mitsuru Kikuchi et al. eds., 2012).

[65] *Id.* at 14.

[66] *Id.* at 26; *Nuclear Fusion Power*, WORLD NUCLEAR ASS'N, https://world-nuclear.org/information-library/current-and-future-generation/nuclear-fusion-power.aspx (Dec. 2022) [hereinafter WNA Fusion] [https://perma.cc/VFQ5-GTBB].

[67] KAW & BANDYOPADHYAY, *supra* note 64, at 26–27.

[68] *Id.* at 27–30.

[69] *Id.*

[70] *Id.* at 29.

[71] *Id.* at 27, 35.

[72] *Id.* at 36–37.

reactions may then be released as heat, driving additional fusion working outwards from the initial implosion site.[73]

In either design, when deuterium-tritium fuel is used, the fusion reaction generates a single helium atom, $^{4}_{2}$He, and a single neutron.[74] Energy from the fusion reaction is imparted as kinetic energy to both of these products.[75] To capture this energy and generate additional fuel, it is proposed that the reaction chamber will be lined with lithium, composed of both $^{7}_{3}$Li and $^{6}_{3}$Li, which have a small probability to capture the neutrons and subsequently decay back into tritium and helium ions.[76] Those neutrons that are not captured generate heat within the lithium "blanket," which can be used to heat water, similar to how fission reactors convert kinetic energy to usable heat.

Since the energy capture mechanism of fusion is from these high-energy neutrons, it is inevitable that the materials in proximity to the reaction chamber may become activated and thus radioactive.[77] The harsh thermal and radiation environment can also result in these materials degrading into dust, which presents a chemical and radiological hazard if it breaches the reaction chamber.[78] Lithium itself presents an explosion, corrosion, and fire hazard, especially in the liquid form preferable to its use as a fusion blanket.[79] Although fusion power does not generate radioactive daughter products like fission, tritium is itself radioactive and must be contained within the plant to avoid environmental contamination, a well-

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73. KAW & BANDYOPADHYAY, *supra* note 64, at 36–37.

74. *See supra* notes 45–46 and accompanying text.

75. *See supra* notes 29–32 and accompanying text.

76. D. Fasel & M.Q. Tran, *Availability of Lithium in the Context of Future D–T Fusion Reactors*, 75 FUSION ENG'G & DESIGN 1163, 1164 (2005); *Tritium Breeding*, ITER, https://www.iter.org/mach/TritiumBreeding (last visited Nov. 22, 2023) [https://perma.cc/8MPA-YUVL].

77. Baojie Nie et al., *Insights into Potential Consequences of Fusion Hypothetical Accident, Lessons Learnt from the Former Fission Accidents*, 245 ENV'T POLLUTION 921, 922 (2019).

78. *Id.*

79. D. N. Ruzic et al., *Liquid-Lithium as a Plasma Facing Material for Fusion Reactors* 1–3 (Ctr. for Plasma Material Interactions, Working Paper, 2017); FUSION ENERGY SCIS. ADVISORY COMM., TRANSFORMATIVE ENABLING CAPABILITIES FOR EFFICIENT ADVANCE TOWARD FUSION ENERGY 61 (2018).

known hazard already associated with fission power plants.[80]

Although the nature of a containment failure in a fusion plant is thus considerably different from that of fission power plants, containment of radioactive material is still the primary safety concern. Localized instabilities, power excursions, magnet quenching, or failures of the coolant system could result in melting or structural breaching of the reaction chamber walls.[81] If the vacuum of the reaction vessel is breached, allowing air and water to enter, chemical reactions with vessel materials can generate hydrogen, resulting in conditions for a hydrogen explosion.[82] Such breaches of the reaction chamber would allow for not only the release of tritium fuel, but the release of other activated dust.

All that said, even if worst-case scenarios are realized, the overall immediate net risk to the public-at-large in the event of a fusion reactor accident will likely remain low.[83] But less risk is not equivalent to no risk, and there nonetheless exists the possibility of impacts to the public if an incident at a fusion plant were to occur.

C. The Price-Anderson Act

One of the first major amendments to the Atomic Energy Act of 1954, the PAA was enacted on September 2, 1957, with the express purpose to "protect the public and to encourage the development of the atomic energy industry"[84] by ensuring there would be some source of funds to cover damages resulting from a nuclear incident,

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[80] *E.g.*, *Backgrounder on Tritium, Radiation Protection Limits, and Drinking Water Standards*, U.S. NUCLEAR REGUL. COMM'N, https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html (Oct. 18, 2022) [https://perma.cc/YTU6-6G3S].

[81] Ruzic et al., *supra* note 79, at 1; R. Redlinger et al., *3D-Analysis of an ITER Accident Scenario*, 75 FUSION ENG'G AND DESIGN 1233, 1234 (2005); Brad J. Merrill, *Modeling an Unmitigated Thermal Quench Event in a Large Field Magnet in a DEMO Reactor*, 98–99 FUSION ENG'G AND DESIGN 2196, 2197–98 (2015).

[82] Redlinger et al., *supra* note 81, at 1234.

[83] FUSION SAFETY AUTH., UK ATOMIC ENERGY AUTH., TECH. REP. – SAFETY AND WASTE ASPECTS FOR FUSION POWER PLANTS 3 (2021).

[84] Price-Anderson Act of 1957, Pub. L. No. 85-256, § 1 (codified as amended at 42 U.S.C. §§ 2014, 2210).

while at the same time limiting the liability of nuclear operators.[85] The modern PAA achieves this by requiring reactor operators to obtain significant liability insurance and establishing corresponding government indemnification obligations for these operators, as well as other contactors and licensees.[86] This insurance acts as the primary payout pool for a nuclear incident.[87]

The core insurance and indemnification functions of the PAA have remained relatively constant over its sixty-five-year lifetime. The most significant changes to the PAA since its enactment were in the Price-Anderson Amendments Act of 1988, which expanded the scope of the PAA to all DOE nuclear contractors, broadened its definition of applicable nuclear incidents, and established a PAA public liability action as an exclusively federal cause of action.[88] So, defendants who are subject to plaintiff tort claims resulting from a nuclear incident can expressly remove the litigation to the federal court system for resolution as a PAA public liability action.[89]

The government indemnification applies to both NRC licensees and DOE contractors.[90] To ensure there will be no runaway liability borne by a nuclear operator following an incident, there is an aggregate limit to damages that must be paid by indemnified parties from a nuclear incident.[91] This limit varies depending on the type of licensee, contractor, or operator.[92] If the aggregate limit exceeds the insurance required of the operator,

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[85] *Id.*

[86] *See* 42 U.S.C. § 2210(a)–(d) (sections a and b establishing requirements for reactor licensees to secure "financial protection" based on the licensed activity, except for power plants producing in excess of 100,000 kW, which must maintain the "maximum amount" of insurance available; sections c and d mandating that government indemnification be available to NRC licensees and DOE contractors, respectively).

[87] MARK HOLT, CONG. RSCH. SERV., PRICE-ANDERSON ACT: NUCLEAR POWER INDUSTRY LIABILITY LIMITS AND COMPENSATION TO THE PUBLIC AFTER RADIOACTIVE RELEASES 1 (2018); ARCENEAUX ET AL., *supra* note 8, at xvii.

[88] Price-Anderson Amendments Act of 1988, Pub. L. No. 100-408, § 2210(d), 102 Stat. 1066 (1988) (codified as amended in scattered sections of 42 U.S.C.).

[89] 42 U.S.C. § 2210(n).

[90] *Id.* § 2210(c)–(d).

[91] *Id.* § 2210(e)(1).

[92] *Id.*

government indemnification funds cover the gap, up to a maximum of $500 million, and even then only up to the upper aggregate liability limit.[93] If the liability resulting from a nuclear incident exceeds that of the aggregate limit, Congress can "take whatever action is determined to be necessary . . . to provide full and prompt compensation to the public" for additional damages.[94]

The PAA requires that for reactors licensed as "utilization" or "production" facilities with a rated capacity of 100,000 kilowatts (kW) or more, NRC licensees must purchase the maximum amount of insurance available, as evaluated by the NRC, per reactor.[95] The current NRC-mandated amount of required primary insurance for such licensees is $450 million per reactor.[96] The amount required for test and low-power reactors is considerably less, on the order of one to three million dollars.[97] If a nuclear incident occurs, all high-power licensees must also contribute to a secondary, deferred premium insurance pool for each covered reactor in the amount of $95.8 million in 2005 dollars (currently inflation-adjusted to $131 million).[98]

The amount of aggregate liability for high-power operators is set to the amount of the maximum financial protection available.[99] Consider that there were ninety-three operating commercial reactors in the United States as of August 1, 2023.[100] If a nuclear incident occurred involving a single reactor, the insurance coverage would baseline at $450 million, and the pooled secondary premium from the ninety-three operating reactors would

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[93] *Id.* § 2210(c)–(d).

[94] *Id.* § 2210(e)(2).

[95] 42 U.S.C. § 2210(a)–(b) (stating that commercial licensees licensed under 42 U.S.C. § 2134, the licensing for production or utilization facilities, "shall" be required to obtain insurance as directed by the NRC, with limits defined for those producing 100,000 kW or more).

[96] 10 C.F.R. § 140.11(a)(4).

[97] *Id.* § 140.11(a)(1)–(3).

[98] 42 U.S.C. § 2210(b); *see also* 10 C.F.R. § 140.11(a)(4).

[99] 42 U.S.C. § 2210(e)(1)(A).

[100] *Nuclear Explained: U.S. Nuclear Industry*, U.S. ENERGY INFO. ADMIN. https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php (Aug. 24, 2023) [https://perma.cc/6TSU-AK64].

contribute an additional $12.183 billion. Thus, the aggregate liability limit for a reactor generating 100,000 kW or more is over $12.5 billion from the insurance pools alone. It has been observed that government indemnification funds, which would otherwise be available for bridging the liability gap up to $560 million, have thus been effectively eliminated for high-power reactor operators.[101] Even if only a single high-power reactor were operational in the U.S., with a primary insurance requirement of $450 million and a retrospective payout of $131 million, the total financial protection would exceed $560 million.

Nonetheless, consider for a moment that the cost of the cleanup from the Fukushima disaster has been estimated at over $600 billion.[102] Compared to such a number, the liability cap of $12 billion for the U.S. nuclear power industry appears minuscule. For large operators, the liability limit provides an incentive to remain in the nuclear power space; for smaller operators, the availability of government indemnification funds provides an incentive to enter it.

II. INTERPRETING FUSION-RELEVANT PROVISIONS OF THE PRICE-ANDERSON ACT

A complete analysis of every definition of the PAA is beyond the scope of this work. Since the challenge of applying the PAA to fusion technologies is mostly one of technical definitional challenges, this paper and this section will focus on the most pertinent definitions of the PAA to the specifics of nuclear power—the definitions of "atomic energy," "nuclear incident," "utilization facility," "production facility," and the various definitions pertaining to types of nuclear material. Furthermore, this section will examine the existing jurisprudence relating to these

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[101] *E.g.*, ARCENEAUX ET AL., *supra* note 8, at xxiv.

[102] *Accident Cleanup Costs Rising to 35-80 Trillion Yen in 40 Years,* JAPAN CTR. FOR ECON. RSCH. (July 3, 2019), https://www.jcer.or.jp/english/accident-cleanup-costs-rising-to-35-80-trillion-yen-in-40-years (35 trillion yen is $268 billion; 80 trillion yen, $612 billion) [https://perma.cc/3ZYP-WZ3T].

definitions and other parts of the PAA that implicate fusion power facilities.

A. "Atomic Energy"

The current chapter of the U.S. Code that houses the provisions of the PAA, Chapter 23 of Title 42, is particularly titled the "Development and Control of Atomic Energy."[103] The phrase "atomic energy" is pertinent to PAA litigation since it is used in the definition of what constitutes a "utilization facility,"[104] one of the categories for which NRC licensure might be required and thus one of the categories of facilities for which the PAA applies.[105]

"Atomic energy" itself is specifically defined as "all forms of energy released in the course of nuclear fission or nuclear transformation."[106] There has not been a major PAA case that has examined or analyzed what sort of processes might be encompassed under the phrase "nuclear transformation" in this definition.

B. "Nuclear Incident"

More controversial in PAA litigation is what defines a "nuclear incident," a threshold criterion for the PAA's public liability provisions to even apply. The definition of "public liability" is "any legal liability arising out of or resulting from a nuclear incident or precautionary evacuation" with exceptions for claims related to worker's compensation, claims relating to acts of war, and claims relating to property loss located at and used at the incident site.[107] The Act itself defines a nuclear incident as:

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[103] 42 U.S.C. § 2011.

[104] *Id.* § 2014(cc).

[105] *Id.* § 2132.

[106] *Id.* § 2014(c).

[107] 42 U.S.C. § 2014(w) (defining "public liability"); 42 U.S.C. § 2210(c)–(e) (defining the indemnification agreement as being applicable to licensees and contractors for liability arising from "nuclear incidents" and limiting the aggregate resultant public liability for a single "nuclear incident"); 42 U.S.C. § 2210(n)(2) ("With respect to any public liability action arising out of or resulting from a nuclear incident, the [applicable federal district court] shall have original jurisdiction . . . .").

> [A]ny occurrence, including an extraordinary nuclear occurrence, within the United States causing, within or outside the United States, bodily injury, sickness, disease, or death, or loss of or damage to property, arising out of or resulting from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material . . . .[108]

"Extraordinary nuclear occurrence" is itself defined as:

> [A]ny event causing a discharge or dispersal of source, special nuclear, or byproduct material from its intended place of confinement in amounts offsite, or causing radiation levels offsite, which the [NRC] or the Secretary of Energy, as appropriate, determines to be substantial, and which the [NRC] or the Secretary of Energy, as appropriate, determines has resulted or will probably result in substantial damages to persons offsite or property offsite.[109]

The NRC or DOE finding that an "extraordinary nuclear occurrence" has or has not occurred is considered final and unreviewable by any hearing court.[110]

Since establishment of a nuclear incident's occurrence is a threshold element to bringing (or barring) a PAA public liability claim, its definition is often contested in such PAA cases. Two questions often raised are particularly relevant for examining the applicability of PAA to fusion plants: (1) what sort of radiation release or exposure qualifies as a "nuclear incident," and (2) must the incident take place at an indemnified site to fall within the scope of the definition?

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[108] 42 U.S.C. § 2014(q) (explaining the section's applicability to international incidents involving NRC licensees or U.S. contractors; this definition is not relevant here).

[109] *Id.* § 2014(j).

[110] *Id.*

1. What Is Within the Scope of "Nuclear Incident?"

In the past two decades, circuit courts have largely interpreted the meaning of "occurrence" within the definition of "nuclear incident" extremely broadly; however, meeting the "injury" prong is more difficult.

In October 2021, in *Matthews v. Centrus Energy Corp.,* the Sixth Circuit held that "ongoing releases" of radioactive materials fell under the "occurrence" prong of the definition of "nuclear incident."[111] The plaintiffs in the case had hoped to avoid removal to federal court—as is expressly permitted by the PAA for public liability actions involving a nuclear incident[112]—and had thus argued that the slow release of uranium hexafluoride did not constitute a singular "nuclear incident" and consequently did not fall under the PAA.[113] The Sixth Circuit soundly rejected this argument, citing the dictionary definition of "occurrence" as "something that occurs, happens, or takes place,"[114] as did other circuit courts in making similar holdings.[115]

These other circuit decisions are worth brief examination to establish the wide scope courts have given to the definition of "occurrence" and thus to "nuclear incident." The Third Circuit held that a researcher's prolonged exposure to cesium-137 fit within the definition of an occurrence.[116] The Fifth Circuit reinforced that singular "extraordinary nuclear occurrences" are just a subset of "nuclear incidents," and the distinction between the two further indicates that the full definition of "nuclear incident" includes non-singular occurrences.[117] The Eighth Circuit, just four months after *Matthews*, similarly used the dictionary definition of "occurrence" to include the slow leakage of waste under its scope.[118] Other circuits and

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[111] Matthews v. Centrus Energy Corp., 15 F.4th 714, 724 (6th Cir. 2021).

[112] 42 U.S.C. § 2210(n)(2).

[113] *Matthews*, 15 F.4th at 723–24.

[114] *Id.* at 722–23.

[115] *Id.* at 724.

[116] Estate of Ware v. Hosp. of Univ. of Penn., 871 F.3d 273, 281 (3d Cir. 2017).

[117] Acuna v. Brown & Root, Inc., 200 F.3d 335, 339 (5th Cir. 2000).

[118] *In re* Cotter Corp., 22 F.4th 788, 794 (8th Cir. 2022).

district courts typically take a similarly permissive view of what constitutes an "occurrence."[119]

While it is accepted that the "occurrence" prong of the definition of "nuclear incident" is broad, the opposite is true for establishing that an individual has suffered a qualified "injury"—that is, suffered "bodily injury, sickness, disease, or death, or loss of or damage to property."[120] Generally, an injury, whether to body or property, must be actual and realized to qualify for PAA coverage.

It is widely accepted that bodily injury cannot simply be an increased risk of disease to qualify as an injury under the PAA. In *June v. Union Carbide Corp.*, the Tenth Circuit held that "DNA damage and cell death" resulting from radiation exposure, which increased the risk of disease but had not yet manifested in disease, did not constitute an injury.[121] In cases similar to *June*, the Ninth and Sixth Circuits both held that "subcellular damage" does not constitute a bodily injury.[122] The Fifth Circuit held that the alleged physical injury must be definitively caused by, not just possibly caused or exacerbated by, the radiation exposure.[123]

The Tenth Circuit is the only circuit court to have heard claims only citing *contamination* of property as an injury—and rejected mere contamination as an "injury." In *Cook v. Rockwell International Corp.* (2010), the court held that unless the plaintiffs could demonstrate that plutonium present on their properties had definitively damaged said properties, the plutonium contamination was insufficient to constitute "loss of or damage to

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[119] *See, e.g.*, Cook v. Rockwell Int'l Corp., 618 F.3d 1127, 1139–40 (10th Cir. 2010) (where the Tenth Circuit, although objecting that the plutonium contamination at issue was a "nuclear incident" on other grounds, seemed to accept at face that the contamination itself may constitute an "occurrence"); Dumontier v. Schlumberger Tech. Corp., 543 F.3d 567, 569 (9th Cir. 2008) (holding the same); Cotromano v. United Tech. Corp., 7 F. Supp. 3d 1253, 1257 (S.D. Fla. 2014) (accepting "misuse or improper disposal" of various radionuclides as a "nuclear incident").

[120] 42 U.S.C. § 2014(q).

[121] June v. Union Carbide Corp., 577 F.3d 1234, 1249 (10th Cir. 2009).

[122] *Dumontier*, 543 F.3d at 570–71; Rainer v. Union Carbide Corp., 402 F.3d 608, 621 (6th Cir. 2005).

[123] Cotroneo v. Shaw Env't & Infrastructure, Inc., 639 F.3d 186, 190 (5th Cir. 2011).

property" within the context of establishing a "nuclear incident."[124] The court reasoned that the list of enumerated injuries in the definition was such that if Congress had wished for contamination to be included in it, it would have expressly done so.[125] However, if the plaintiffs had been able to establish a loss of use of the property, there would have been sufficient showing to qualify as an "injury."[126] One district court outside of the Tenth Circuit rejected the *Cook* rule, accepting contamination of property as an allowable PAA injury.[127]

2. Must the "Incident" Occur at an Indemnified Facility?

With its recent decision in *In re Cotter Corp.*, the Eighth Circuit joined the Third and Fifth Circuits in holding that a nuclear incident *need not* occur at an indemnified facility for the provisions of the PAA to apply.[128] In *Cotter*, the fact that the defendant—which owned a nuclear waste site at issue—had no indemnification agreement was deemed irrelevant, and the court held that the PAA grants federal jurisdiction to "all nuclear incidents regardless of whether the defendant had an applicable indemnity agreement."[129] Similarly, in *Acuna v. Brown & Root*, the Fifth Circuit held that a uranium mining facility located in Texas, which regulated its own uranium mining industry and required no federal indemnification agreement for such facilities, was still permitted to invoke the PAA removal provisions despite the lack of an indemnification agreement.[130] The Third Circuit, in *Estate of Ware*, considered exposure to cesium-137 at a university lab as a "nuclear incident" to which the

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[124] *Cook,* 618 F.3d at 1140–41.

[125] *Id.* at 1141.

[126] *Id.* at 1141–42.

[127] Steward v. Honeywell Int'l, Inc., 469 F. Supp. 3d 872, 879 (S.D. Ill. 2020).

[128] *In re* Cotter Corp., 22 F.4th 788, 796 (8th Cir. 2022) (citing Estate of Ware v. Hosp. of the Univ. of Penn., 871 F.3d 273, 283 (3d Cir. 2017) and Acuna v. Brown & Root, Inc., 200 F.3d 335, 339 (5th Cir. 2000)).

[129] *Id.* at 796.

[130] *Acuna,* 200 F.3d at 339.

PAA public liability provisions applied, despite the lack of an indemnification agreement with the NRC.[131]

Thus, although indemnification agreements can be required for various contractors and licensees under the PAA, such agreements are not required to invoke the jurisdiction of the PAA itself. As a result, any claim which alleges an injury at a licensed site which could fall under the definition of "nuclear incident" can be removed to federal court. Such removal often presents strategic advantages to industry defendants—even those without formal PAA indemnity agreements—as some tort claims (such as emotional distress) simply do not meet the definition of "injury" requisite in the PAA, and many courts have held that any state claims arising under an established "nuclear incident" are preempted.[132] Indeed, the three circuit cases that formulated this rule all came to appeals based on a defendant's motion to remove and the plaintiff's subsequent objection to the removal.[133]

The *Cotter* court expressly rejected a series of decisions in the Eastern District of Missouri which held that an indemnity agreement *was* required for PAA removal.[134] At least one district court outside of the Eighth, Third, and Fifth Circuits has limited the PAA's applicability to the nuclear energy and nuclear weapons industries, but not necessarily only to indemnified licensees and contractors.[135] The question of whether a license or contract is required for the PAA to apply was considered by the *Estate of Ware* court, but left unresolved, as the state license involved there was determined to be sufficient regardless of whether such a requirement exists;

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[131] *Estate of Ware*, 871 F.3d at 283.

[132] *E.g.*, McGlone v. Centrus Energy Corp., 2020 WL 4431482, *6 (S.D. Ohio July 31, 2020); Pinares v. United Tech. Corp., 2018 WL 10502426, *4 (S.D. Fla. Nov. 14, 2018).

[133] *In re Cotter Corp.*, 22 F.4th at 791; *Estate of Ware*, 871 F.3d at 277; *Acuna*, 200 F.3d at 338.

[134] Strong v. Republic Servs., Inc., 283 F. Supp. 3d 759, 767–72 (E.D. Mo. 2017); Banks v. Cotter Corp., 2019 WL 1426259, *8 (E.D. Mo. Mar. 29, 2019); Kitchin v. Bridgeton Landfill, 389 F. Supp. 3d 600, 611 (E.D. Mo. 2019).

[135] Samples v. Conoco, Inc., 165 F. Supp. 2d 1303, 1321 (N.D. Fla. 2001).

some district courts have suggested that there is a license or contract requirement.[136]

C. "Utilization Facility" and "Production Facility"

The NRC has statutory authority to require licenses for "utilization and production facilities for industrial and commercial purposes."[137] It has exercised this authority through the promulgation of regulations that require a license to operate such facilities, with limited exceptions.[138] The PAA requires insurance for such licensees; while the amount of insurance varies per type of facility, the indemnification provisions uniformly apply.[139] As defined in the Atomic Energy Act, a "utilization facility" is:

> [A]ny equipment or device, except an atomic weapon, determined by rule of the [NRC] to be capable of making use of special nuclear material in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public, or peculiarly adapted for making use of atomic energy in such quantity as to be of significance to the common defense and security, or in such manner as to affect the health and safety of the public . . . .[140]

The definition also includes "any important component part" of such devices as the NRC determines.[141]

The NRC made use of this delegated authority to define a "utilization facility" as:

> (1) Any nuclear reactor other than one designed or used primarily for the formation of plutonium or U-233; or

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[136] *Estate of Ware*, 871 F.3d at 283–84 (3d Cir. 2017) (citing Irwin v. CSX Transp., Inc., 2011 WL 976376, *2 (E.D. Tenn. Mar. 16, 2011) and Samples v. Conoco, Inc., 165 F. Supp. 2d 1303, 1321 (N.D. Fla. 2001)).

[137] 42 U.S.C. § 2134(b).

[138] 10 C.F.R. § 50.10(b) (Exceptions include Department of Defense contractors and common carriers transporting material to and from utilization and production facilities.); *see generally* 10 C.F.R. § 50.11.

[139] 42 U.S.C. § 2210(a)–(c).

[140] 42 U.S.C. § 2014(cc).

[141] *Id.*

> (2) An accelerator-driven subcritical operating assembly used for the irradiation of materials containing special nuclear material . . . .[142]

"Nuclear reactor" is subsequently defined as "an apparatus, other than an atomic weapon, designed or used to sustain nuclear fission in a self-supporting chain reaction."[143]

Courts have held that, in determining what constitutes a "utilization facility," the NRC definition supersedes the Atomic Energy Act (AEA) definition when resolving disputes over the term.[144] Courts have also held that, when viewing the definition of "utilization facility" alongside that of "nuclear reactor," the actual sustainment of fission in a facility is of less importance than its *ability* to sustain fission.[145] Courts have also given broad deference to the NRC's interpretation of "component part[s]" including transmission lines from nuclear power plants under the umbrella of "utilization facilities."[146]

The definition for "production facility" in the AEA is extremely similar to that of "utilization facility," with the "capable of making use of" language instead reading "capable of the *production* of" special nuclear material.[147] Uranium isotope separation and uranium-235 enrichment devices are expressly exempt from the definition.[148]

Again, the NRC definition of "production facility" is starkly different from the AEA definition. The NRC defines a "production facility" as:

> (1) Any nuclear reactor designed or used primarily for the formation of plutonium or U-233; or

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[142] 10 C.F.R. § 50.2.

[143] *Id.*

[144] *E.g.*, Nuclear Dev. v. Tenn. Valley Auth., 532 F. Supp. 3d 1154, 1175 (N.D. Ala. 2021) ("A utilization facility, in other words, is what the NRC says it is.").

[145] *Id.* at 1172.

[146] Detroit Edison Co. v. U.S. Nuclear Regul. Comm'n, 630 F.2d 450, 452–54 (6th Cir. 1980); Pub. Serv. Co. of N.H. v. U.S. Nuclear Regul. Comm'n, 582 F.2d 77, 82–83 (1st Cir. 1978).

[147] *Compare* 42 U.S.C. § 2014(v) (emphasis added) (defining "production facility"), *with* 42 U.S.C. § 2014(cc) (defining "utilization facility").

[148] 42 U.S.C. § 2014(v).

> (2) Any facility designed or used for the separation of the isotopes of plutonium [except for research purposes]; or
> (3) Any facility designed or used for the processing of irradiated materials containing special nuclear material, except [experimental facilities, facilities using only small amounts of uranium-235, and batch uranium-based waste processors] . . . .[149]

When the term has been used by courts, it has typically been in a way that makes it readily apparent the facility in question is a production facility, most commonly with weapons production facilities.[150]

D. Material Definitions

Many of the definitions discussed previously make reference to particular types of nuclear material: "source material," "special nuclear material," and "byproduct material." The PAA provides for the NRC to optionally require insurance for licensees that are regulated via the use of such materials (as opposed to mandating coverage for utilization and production facilities).[151] Source material is the most straightforward of the group, defined as: "[U]ranium, thorium, or any other material which is determined by the [NRC] . . . to be source material; or ores containing one or more of the foregoing materials, in such concentration as the [NRC] may . . . determine . . . .[152] The NRC, although making use of its authority to specify the concentration at which ores become "source material" (0.05%), has not expanded the substantive definition beyond that of uranium and thorium.[153] To do so, it must determine that the material is "essential to the production of special nuclear material."[154]

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[149] 10 C.F.R. § 50.2 (2023).

[150] *E.g.*, *In re* Hanford Nuclear Rsrv. Litig., 534 F.3d 986, 995 (9th Cir. 2008).

[151] 42 U.S.C. § 2210(a).

[152] 42 U.S.C. § 2014(z).

[153] 10 C.F.R. § 40.4.

[154] 42 U.S.C. § 2091.

"Source material" is expressly defined as *not* "special nuclear material."[155] "Special nuclear material" includes "plutonium, uranium enriched in the isotope 233 or in the isotope 235," or "any material artificially enriched by any of the foregoing."[156] Again, the AEA grants the NRC discretion to define other materials as "special nuclear material" if it determines that "such material is capable of releasing substantial quantities of atomic energy."[157] As with "source material," the NRC has not used this discretion to designate any material other than plutonium and the named uranium isotopes as special nuclear material.[158]

The definition of "byproduct material" encompasses many more types of nuclear materials. The AEA defines "byproduct material" as:

> (1) [A]ny radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;
> (2) the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore . . . ;
> (3) (A) any discrete source of radium-226 . . . ; or
>   (B) any material that–
>   (i) has been made radioactive by use of a particle accelerator; and
>   (ii) is produced, extracted, or converted . . . for use for a commercial, medical, or research activity; and
> (4) any discrete source of naturally occurring radioactive material, other than source material, that [poses a particular public health threat akin to that of radium-226].[159]

The NRC does not have the authority, as it does with "source material" and "special nuclear material," to define its own scope of "byproduct material." It has, however,

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[155] 42 U.S.C. § 2014(aa).
[156] *Id.*
[157] 42 U.S.C. § 2071.
[158] *Id.*; 10 C.F.R. § 40.4.
[159] 42 U.S.C. § 2014(e) (compare with 10 C.F.R. § 30.4).

exempted certain quantities and concentrations of byproduct material in certain products from various licensure and handling requirements; these include tritium-luminescent watches, americium-based smoke detectors, and tritium-precision balances.[160]

When the "byproduct material" provision is contested in litigation, it is often within the context of nuclear waste, especially since the "tailings or wastes" provision was added in the late 1970s.[161] Notably for fusion analysis, there has indeed been a case that considered whether tritium exposure constituted a release of "byproduct material" in the context of the PAA. In *Gassie v. SMH Swiss Corp.*, plaintiffs alleged that tritium in their timepieces had leeched out and caused them "cell disruption,"[162] bringing state law tort claims against the manufacturer, SMH Swiss.[163] SMH Swiss removed to the Eastern District of Louisiana, citing that the alleged injury was a PAA claim involving a "nuclear incident."[164] The court held that it did indeed have subject matter jurisdiction under the PAA and dismissed the case for failure to state a cognizable injury.[165]

On appeal, the Fifth Circuit specifically remanded the decision back to the lower court for the lower court's failure to determine if either *all* tritium was considered "byproduct material" or if the tritium *at hand* was "byproduct material."[166] On remand, the district court held that not *all* tritium was byproduct material since some tritium is naturally occurring; but the tritium at hand *was* byproduct material since it had been supplied to SMH

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[160] 10 C.F.R. § 30.15 (Otherwise, consider that any homeowner with a smoke detector would need an NRC license to possess any non-naturally occurring americium).

[161] *E.g.*, United States v. Manning, 527 F.3d 828, 831 (9th Cir. 2008) (considering if mixed chemical and radioactive waste qualified as a "byproduct material"); Strong v. Republic Servs. Inc., 283 F. Supp. 3d 759, 772–73 (E.D. Mo. 2017) (considering if waste not expressly described as mill tailings qualified as "byproduct material").

[162] Gassie v. SMH Swiss Corp., 1998 WL 158737, at *1 (E.D. La. Mar. 26, 1998).

[163] *Id.*

[164] *Id.* at *2.

[165] *Id.* at *3–6.

[166] Gassie v. SMH Swiss Corp., 1998 WL 870323, at *2 (5th Cir. Nov. 24, 1998).

Swiss from a nuclear reactor.[167] Thus, the original dismissal of the plaintiff's claims was upheld.[168]

The definition of "byproduct material" is further relevant for fusion analysis of the PAA since it brings "particle accelerators" into the fold. "Particle accelerator" is not defined in the AEA. The NRC defines "particle accelerator" as: "[A]ny machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 megaelectron volt."[169] The definition of "particle accelerator" or its relationship to "byproduct material" has not been a significant part of any major PAA case. However, as will be discussed *infra*, current and suggested regulatory policy has considered whether, and how, fusion reactors fit the definition of "particle accelerator" and thus could be regulated under this prong of NRC authority regulating facilities making use of "byproduct material."[170] Such classification implicates whether an incident at a fusion facility may qualify as a PAA-scoped "nuclear incident."

III. CONSIDERING A "NUCLEAR INCIDENT" AT A FUSION PLANT IN THE CONTEXT OF PRICE-ANDERSON PUBLIC LIABILITY

The definitions discussed *supra* are the primary provisions in considering whether fusion power plants may fall under the PAA insurance scheme. Whether fusion power plants as a whole fall under the greater NRC

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[167] Gassie v. SMH Swiss Corp., 1999 WL 539489, at *2–3 (E.D. La. July 22, 1999).

[168] *Id.* at *3.

[169] 10 C.F.R. § 30.4 (2014).

[170] NRC FUSION MEMORANDUM, *supra* note 2 at 16–18; NRC FUSION DECISION, *supra* note 2, at 1 (citing "Option 2" of the staff's recommendation, the byproduct materials regulatory pathway, as the preferred approach); Sachin Desai, Gen. Couns., Helion Energy, Perspectives on an Appropriate Regulatory Framework for Fusion, Address at the NRC Briefing on Regulatory Approaches for Fusion Energy Devices (Nov. 8, 2022); 10 C.F.R. § 30.3 (providing that "no person shall manufacture, produce, transfer, receive, acquire, own, possess, or use byproduct material except as authorized in a specific or general license" issued by the NRC, where "byproduct material" includes material made radioactive from particle accelerators, as detailed in the definition *supra* note 159).

regulatory and licensing scheme is implicated in such an analysis since the type of license impacts both the scope of the PAA's provisions and whether insurance is required to be sought or can optionally be sought as part of a license.

Should fusion plants be regulated under current licensing schemes, they would need to be classified as either a "utilization facility" or as a user of "byproduct material."[171] The NRC staff, in its recommendations to the NRC earlier this year, considered both of these options, and recommended a "hybrid approach."[172] Under this approach, whether a particular plant is regulated as a utilization facility or byproduct material handler would be determined by the hazards presented by the particular plant.[173] Generally, industry observers have resisted classification of fusion plants as "utilization facilities" due to the cost burden and risk-sharing nature of the PAA insurance buy-in, additional licensing requirements imposed by such classification, and restrictions on foreign export.[174] Regulation under the byproduct materials framework has been met with a comparatively warmer response[175]—with some states already regulating fusion devices as particle accelerators.[176] However, this regulation is less likely to be adequate for commercial-size reactors, and there are challenges in fitting the materials generated by fusion into the various definitions.[177] Ultimately, the NRC directed its staff to pursue the latter pathway: regulating fusion devices under the existing byproduct materials framework and developing regulatory guidance as required.[178]

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[171] NRC FUSION MEMORANDUM, *supra* note 2, at 2.

[172] *Id.*

[173] *Id.*

[174] *E.g.*, DAVID R. LEWIS ET AL., CONSIDERATIONS IN THE REGULATION OF FUSION-BASED POWER GENERATION DEVICES 2 (2020).

[175] *E.g.*, Desai, *supra* note 170 (advocating for the byproduct materials framework); AMY C. ROMA & SACHIN S. DESAI, THE REGULATION OF FUSION – A PRACTICAL AND INNOVATION-FRIENDLY APPROACH 2 (Feb. 2020) (advocating for the same).

[176] *E.g.*, Megan Shober, Nuclear Safety Specialist, Wisconsin Radioactive Materials Program, Licensing Fusion Devices, Address at the NRC Briefing on Regulatory Approaches for Fusion Energy Devices (Nov. 8, 2022) (describing Wisconsin's approach to regulating research fusion devices as particle accelerators).

[177] LEWIS ET AL., *supra* note 174, at 3.

[178] NRC FUSION DECISION, *supra* note 2, at 1.

Regardless, from a public liability perspective, the judicial trend suggests that the precise process for licensing fusion plants does not necessarily matter—a PAA claim can be raised regardless of whether the licensure agreement requires indemnification. The aggregate limit on public liability, however, applies only to "persons indemnified."[179] Courts have also indicated a fair amount of deference to the NRC's classification of facilities and materials when analyzing PAA claims, so it follows that the definitions that the NRC adopts with respect to fusion facility regulation may carry some weight should a related PAA claim arise. Finally, the fusion accidents underlying the claims need not be at the scale of the Three Mile Island Accident or massive contamination to be raised; if fusion plants are to eventually be part of the U.S. energy infrastructure, even small incidents could be subject to PAA scrutiny.

This section considers how the definitions and judicial case law described above may influence the outcome of a public liability action raised under the PAA, in the context of a hypothetical accident at a future commercial-scale fusion plant.[180] Implications of some of these legal ambiguities will be explored, and consideration will be given to how some of the raised ambiguities and questions could be resolved proactively, before fusion becomes an established part of the energy grid, especially given the current appetite for regulatory updates in the nuclear energy sector.

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[179] 42 U.S.C. § 2210(e)(1).

[180] Current NRC discussions focus on the regulation of near-term deployment of fusion systems, on the 2030 timescale. NRC FUSION MEMORANDUM, *supra* note 2, at 1. These reactors would be on the order of 50 MW capacity. The hypothetical described would be considerably further in the future, to reach true commercial scale, such as the 500 MW output anticipated in the first ITER experiments. *What Is ITER?*, ITER, https://www.iter.org/proj/inafewlines (last visited Nov. 22, 2023).

A. *Establishing a Hypothetical Scenario: A Hydrogen Explosion Resulting in Radioactive Material Release*

In this scenario, several decades from now, commercial fusion reactors are deployed on a scale far beyond their 2023 contemporaries, providing in excess of the 500 MW capacity of even the largest modern experiments.[181] A 1 GW capacity, self-fueled (breeding tritium while absorbing energy through a lithium blanket that lines the reaction chamber) tritium-fueled fusion plant experiences a superconducting magnet quenching event, which generates enough energy to rupture the reaction vacuum chamber[182] and, regrettably, break a water-coolant pipe. The pressure differential allows water from the ruptured pipe to rapidly intrude into the chamber and react with materials within the chamber to produce hydrogen. The latent heat in the reaction chamber causes this hydrogen to ignite, causing an explosion. The explosion causes the release of all tritium in the reactor, 1 kg, as well as 100 kg of activated tungsten dust from the interior of the reaction chamber, into the environment.[183] The resultant activity is orders of magnitude less than that of the accidents at Fukushima and Chernobyl, but is a release nonetheless large enough to warrant a rating of "serious" on accident severity scales.[184] Those people within 1 kilometer downwind of the plant receive a potentially lethal radiation dose if evacuation is delayed.[185] Evacuations are ordered in the surrounding 10 kilometers of the plant; those within have an increased risk of cancer for the rest of their lives.[186] A local waterway is

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[181] *E.g.*, *What Is ITER?, supra* note 180.

[182] *See* Nie et al., *supra* note 77, at 922 (It should be noted that the accident described would be a beyond-design basis event, which under current and proposed NRC regulations, would have an expected occurrence probability too low to fully consider in the design process).

[183] *Id.* at 924.

[184] *Id.* at 924–25.

[185] *Id.* at 926.

[186] *Id.*

contaminated, and remediation of the evacuation area takes fifty years.[187]

B. Fulfilling PAA "Nuclear Incident" Criteria

Recalling the discussion above, to qualify as a "nuclear incident" subject to PAA jurisdiction, an occurrence must cause a tangible injury resulting from the "radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material."[188]

In the given scenario, it is apparent that any direct injury—such as a direct radiation injury or cancer traceable to the exposure—would likely qualify, especially if readily traceable to the activated dust release. For those who could only demonstrate an increased risk of illness, injury would not be demonstrated under the current precedential case law, but any loss of property could satisfy the injury requirement. Under the *Cook* framework, any ground or waterway contamination would not alone qualify as an injury, absent a loss of use of property or other related injury. It is possible, however, that other courts might consider contamination to be a valid injury.

From a materials perspective, tritium or any activated isotopes from a fusion reactor—such as tungsten in this scenario, but also including any lithium generated from neutron absorption—would not qualify as source or special nuclear material under the baseline definitions. Neither material is or is derived from uranium, thorium, or plutonium; unless the NRC exercises its authority to define any fusion-related fuels or resultant products as either material, the scenario described does not satisfy the last "nuclear incident" prong as source or special nuclear material.

The last qualifying material is "byproduct material." The byproduct material framework has been noted to possibly be inadequate at scale,[189] but in the context of

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[187] *Id.* at 930.

[188] 42 U.S.C. § 2014(q).

[189] *See* NRC FUSION MEMORANDUM, *supra* note 2, at 18; *see* ROMA & DESAI, *supra* note 175, at 2.

establishing a nuclear incident, a court would only need to establish whether the radioactive materials in question are byproduct materials. Recall that byproduct material encompasses a broad swath of radioactive materials, including material made radioactive by exposure to special nuclear material, material made radioactive "by use of a particle accelerator" for a "commercial, medical, or research" purpose, and any naturally occurring source of radioactive material extracted for the same purposes that poses a public health threat similar to that of radium-226.[190]

It should be noted that many fusion research facilities today fall under the "byproduct material" umbrella by virtue of their use of tritium.[191] Tritium rarely naturally occurs, and the seed fuels used in research (and weapons) today are from commercial fission reactors.[192] Since the tritium is produced via the fission process, which uses uranium fuel, it qualifies as the first type of byproduct material "yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear material."[193]

Any fusion reactor is likely to start its reactions with fission reactor-generated tritium. It is apparent from the statutory definition, and in a court analysis in alignment with *Gassie*, that such tritium would qualify as a "byproduct material." The tritium generated in a lithium blanket within the plant, however, would not meet the current definition of "byproduct material." The activated lithium would not itself be a special nuclear material, so any tritium produced as a result of its decay would not meet the definition.

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[190] *See supra* notes 160–71 and accompanying text.

[191] ROMA & DESAI, *supra* note 175, at 10–11.

[192] Catherine Clifford, *This Government Lab in Idaho Is Researching Fusion, the 'Holy Grail' of Clean Energy, as Billions Pour into the Space*, CNBC (May 28, 2022, 9:00 AM), https://www.cnbc.com/2022/05/28/idaho-national-lab-studies-fusion-safety-tritium-supply-chain.html [https://perma.cc/H3QL-27D2]; Ben Cathey, *Watts Bar Lone Source of a Nuclear Weapon Material; TVA Increasing Production*, WVLT 8 (May 24, 2022, 4:51 PM), https://www.wvlt.tv/2022/05/24/watts-bar-lone-source-nuclear-weapon-material-tva-increasing-production/ [https://perma.cc/7ZBA-E5XN].

[193] 42 U.S.C. § 2014(e).

Arguing for the inclusion of fusion products under the radium prong is so difficult as to be infeasible, but for the sake of completeness it warrants a passing thought. Radium-226 is generated through the natural, environmental decay of uranium-238, and poses a public health risk due to its carcinogenic properties.[194] The release of tritium into the water supply would pose a similar threat. What precisely "naturally" means is not defined in the AEA, and there are no indications of what constitutes a "natural" generation of radioisotopes in the legislative history. One could thus attempt to argue that radioactive decay is itself a "process of nature," so the production of tritium from the decay lithium, is a "natural" occurrence. Such an argument is a considerable reach, however, especially in light of the plain meaning of the word "natural." Finally, the designation of a material as byproduct material based on its similarity in threat to radium-226 requires not just the opinion of the NRC, but of the Environmental Protection Agency and the Departments of Energy and Homeland Security (at a minimum) as well,[195] presenting a likely inability for a court to determine this designation alone.

As mentioned previously, licensing of near-term fusion technologies as byproduct material facilities, specifically of materials generated by the classification of fusion facilities as particle accelerators, has been a proposed regulatory avenue.[196] Under current statutes and regulations, this would be the most likely prong up for debate in defining fusion material as "byproduct material" in a theoretical PAA public liability action. Revisiting the definition given by the NRC, a particle accelerator is: "[A]ny machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation

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[194] DELAWARE HEALTH AND SOCIAL SERVICES, RADIUM-226 AND 228 1–2 (2015).

[195] 42 U.S.C. § 2014(e)(4)(A).

[196] Desai, *supra* note 170; NRC FUSION MEMORANDUM, *supra* note 2, at 9–10.

into a medium at energies usually in excess of 1 megaelectron volt."[197]

The NRC's purview over accelerator-produced byproduct material is relatively recent, as it was granted by Congress in the Energy Policy Act of 2005.[198] In describing the development of its definition cited above, the NRC more broadly characterized a particle accelerator as "a device that imparts kinetic energy to subatomic particles by increasing their speed through electromagnetic interactions."[199] Particle accelerators are described as activating nuclei—that is, making them radioactive—by directing beams of fast particles at a specific target, or simply using the accelerated particle beam itself for specific purposes, such as medical treatment.[200] The "beam" nature of particle accelerators was used to characterize them into two types—linear and circular—both using electrical and magnetic fields to direct and focus the beam.[201] This sort of description is consistent with the typical use of the phrase, dictionary definitions,[202] and prototypical examples of particle accelerators, such as the Large Hadron Collider.[203]

While fusion reactors do not accelerate particles in the same sense as the facilities described above, it is nonetheless possible that the first portion of the definition could be argued as being met. Magnetic confinement designs are the most similar to current particle accelerators, as charged particles (deuterium and tritium

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[197] 10 C.F.R. § 30.4.

[198] Energy Policy Act of 2005, Pub. L. No. 109-58, § 651, 119 Stat. 594 (2005).

[199] Requirements for Expanded Definition of Byproduct Material, 72 Fed. Reg. 55864, 55868 (Oct. 1, 2007) (to be codified at 10 C.F.R. pts. 20, 30, 31, 32, 33, 35, 50, 61, 62, 72, 110, 150, 170, 171).

[200] *Id.*

[201] *Id.*

[202] *E.g.*, *Particle Accelerator*, CAMBRIDGE DICTIONARY, https://dictionary.cambridge.org/dictionary/english/particle-accelerator (last visited Nov. 22, 2023) [https://perma.cc/PCQ7-KA5E].

[203] *The Large Hadron Collider*, CERN, https://www.home.cern/science/accelerators/large-hadron-collider (last visited Nov. 22, 2023) (describing the LHC as "the world's largest and most powerful particle accelerator . . . consist[ing] of a 27-kilometre ring of superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way.") [https://perma.cc/HWL4-87HK].

in the reaction considered throughout this paper) follow electromagnetic fields to gain energy.[204] The resultant plasma is itself composed of electrons and charged nuclei. That this energy ultimately results in a reaction different from that of other particle accelerators is arguably of no particular consequence in satisfying the initial "charged particle acceleration" criteria.

Inertial confinement designs, however, are less similar in function to traditionally defined particle accelerators than their magnetic confinement counterparts. But considering that inertial confinement forcibly implodes the fuel pellet, the argument can nonetheless be made that the fuel particles are being accelerated together, almost instantaneously.[205] More precisely, since kinetic energy is what is ultimately being increased, the particles are accelerated by virtue of their velocity increasing. The *type* of acceleration is not defined in the NRC definition.

With respect to the second half of the definition—characterizing the products rather than the device—meeting the energy threshold would likely not be an issue. In the D-T fusion reaction used throughout this work,[206] the total kinetic energy of the daughter products of deuterium-tritium fusion—a neutron and a helium nucleus—possess kinetic energies in excess of 17 MeV, far above the definitional threshold of 1 MeV. Even if the energies were lower, the inclusion of "usually" would nonetheless indicate that a particle need not necessarily possess an energy in excess of 1 MeV to qualify as being generated by a particle accelerator. That they are discharged into a material, in this scenario, could be argued as being strictly met, as it is provided that the products of the reaction are discharged into a lithium blanket.

Yet, are the products of fusion "resultant particulate or other radiation"? Some, including the NRC, have

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[204] *See supra* notes 68–70 and accompanying text.

[205] *See supra* notes 72–74 and accompanying text.

[206] *See supra* notes 45–49 and accompanying text.

suggested the answer to this is yes, while others are more skeptical.[207] The argument for inclusion would need to accept that the fusion products are a result of the preceding particle acceleration. There is thus a need for an implicit acceptance that particles one reaction removed from the initial acceleration are nonetheless "resultant" of the original acceleration. It could also be argued, especially for magnetic confinement designs, that the charged particles are themselves discharged into the greater plasma medium.[208] Since the NRC considers its jurisdiction over the byproduct materials from particle accelerator use to include those byproducts "incidentally" produced by accelerators, if a fusion device were to meet the first part of the definition of an accelerator, the resultant products of fusion could be argued to be "incident" to the initial accelerator products.[209] This would include the activated tungsten from the reactor structure, the helium and neutron products of D-T fusion, and any activated isotopes or tritium generated in the reaction blanket.

The counterargument is that, regardless of the NRC interpretation of its own regulation, a strict textual reading indicates that "resultant" means "resultant to the acceleration interaction." The phrase would thus only apply to the particulate resulting from any reactions derived from the acceleration itself, not to subsequent reactions. Any particles being discharged into a medium, such as any neutrons interacting with the tungsten structure or lithium blanket, would be the products of the *fusion reaction*, not of the acceleration of the fuel itself—

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[207] *Compare* NRC FUSION MEMORANDUM, *supra* note 2, at 4, 10 (taking the resultant daughter products as qualifying), *with* LEWIS ET AL., *supra* note 174, at 3 (taking the resultant particles as not qualifying in the context of the particle accelerator definition).

[208] NRC FUSION MEMORANDUM, *supra* note 2, at 4 (The NRC, in considering whether fusion devices meet this portion of the definition, included discharge into a "plasma, walls, or breeding blankets" as meeting the "discharge the resultant particulate into a medium" prong).

[209] Requirements for Expanded Definition of Byproduct Material, 72 Fed. Reg. 55864, 55868 (Oct. 1, 2007) (to be codified at 10 C.F.R. pts. 20, 30, 31, 32, 33, 35, 50, 61, 62, 72, 110, 150, 170, 171).

the acceleration is merely a step to the particulate generated by the fusion reaction.

With respect to "other radiation," this would appear to capture radiation which may not be considered "particulate" (such as gamma radiation, which is photons). A court making use of textual canons, such as the series-qualifier canon, would likely consider it a straightforward interpretation that "resultant" applies to "other radiation" as well.[210] As such, it is unlikely that this would come into play in any more relevant a sense than arguments regarding particulate.

In any case, in its most recent interpretation of the definition of "particle accelerator," the NRC staff has characterized the operation of fusion reactors as "consistent" with their given definition.[211] Even inertial confinement designs, further from traditional particle accelerators than their magnetic brethren, are neither excluded nor qualified in being included as an accelerator.[212] Should an incident arise at a fusion plant, even at a research plant today, a court might turn to these interpretations for guidance. The NRC staff has further suggested, in its proposed rulemaking plan for fusion reactors, that the NRC revise the definition of "particle accelerator" such that material generated by fusion reactors is captured by the byproduct materials definition.[213] Should the NRC choose to further define "particle accelerator," it may be subject to *Chevron* challenges if the question were to arise in a PAA lawsuit. Instead, if the NRC chooses to leave the definition as-is and rely upon guidance interpreting its rule defining the term, it may be subject to a *Kisor* inquiry leading to a similar lawsuit. Assuming the position at issue is a formal position

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[210] ANTONIN SCALIA & BRYAN A. GARNER, READING LAW: THE INTERPRETATION OF LEGAL TEXTS 13 (2012).

[211] NRC FUSION MEMORANDUM, *supra* note 2, at 10.

[212] *Id.*

[213] NUCLEAR REGUL. COMM'N, RULEMAKING PLAN FOR FUSION ENERGY SYSTEMS 3 (Jan. 3, 2023), https://www.nrc.gov/docs/ML2227/ML22273A175.pdf [https://perma.cc/V9GJ-EQGL].

by the NRC,[214] both inquires would rest on foundations of ambiguity and reasonableness, albeit for either the statute or the regulation at hand.

Some considerations other than those already raised may be pertinent. While some observers have posited that the byproduct materials framework is a natural one for fusion reactors,[215] others have characterized the conclusion of fusion reactors under the scope of "particle accelerators" as "shoehorned" and vulnerable to judicial interpretation.[216] Other legislative history and statutes offer little more insight. The definitions of either "byproduct material" or "particle accelerator" were not a topic during the hearings concerning the Energy Policy Act of 2005.[217] Other statutes making use of the term "accelerator" in the nuclear sense vary in their implementation of the term. Most mentions of accelerators focus on prioritizing DOE science priorities, and couch "accelerators" as being akin to the prototypical and common-language definitions described previously,[218] citing the usefulness of accelerators in advancing particle physics.[219] One specifically separates "accelerators" from "nuclear reactors,"[220] while another is generic in using the term "accelerator machines."[221] It is thus reasonable that the term "particle accelerator" as used in the "byproduct material" definitions is silent with regard to the Energy Policy Act of 2005; additionally, Congress itself has not presented a consistent definition in other legislation. Therefore, its current interpretation would likely be considered a permissible interpretation.

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[214] NRC FUSION DECISION, *supra* note 2, at 1. Note that all guidance discussed supra has been that of agency staff suggestions to the formal NRC, not the position adopted by the NRC itself. In its directive to the staff to pursue the byproduct materials framework for regulating current and near-future fusion plant designs, the NRC did not expressly adopt a position on considering fusion plant "particle accelerators."

[215] ROMA & DESAI, *supra* note 175, at 11–12.

[216] LEWIS ET AL., *supra* note 174, at 3.

[217] *The Energy Policy Act of 2005: Hearings Before the Subcomm. on Energy and Air Quality of the H. Comm. on Energy and Com.*, 109th Cong. (2005).

[218] *See supra* notes 200–04 and accompanying text.

[219] *E.g.*, 42 U.S.C. § 18648; 42 U.S.C. § 18643.

[220] 42 U.S.C. § 18649(b)(5).

[221] 42 U.S.C. § 7384l(16)(E).

Amending the definition might encounter more scrutiny. Although other uses of the term throughout other statutes are not thoroughly consistent, they do not necessarily include fusion reactors under the same umbrella as other "accelerators." Although the definition of "acceleration" can be understood in a strict technical sense to encompass any increase of velocity, fusion reactors are not commonly understood to fall under the umbrella of particle accelerators. Given Congress's other legislation regarding fusion specifically, it would be difficult to argue that it meets the intent of Congress to include fusion plants under the umbrella of particle accelerators, rather than of a type more similar to fission reactors.

Indeed, with respect to interpreting its own rule, the NRC itself did not consider fusion in its initial development of the "particle accelerator" definition.[222] A court making a *Kisor* inquiry could follow the reasoning chains discussed above, assuming no other modifications are made to the definition of "particle accelerator." Yet, the NRC's indication that it wishes to amend its regulations to better include fusion reactors under the definition of "particle accelerators" arguably indicates an implication that the current definition is insufficient to include them.

Historically, the NRC has enjoyed a great deal of deference from the courts regarding its highly technical area of expertise. However, the inclusion of fusion reactors as a subset of particle accelerators—whether under a new form of the definition interpreting the Energy Policy Act of 2005 or under its current definition—could strain credulity and would likely be subject to extensive judicial review.

C. Resolving Ambiguities Before an Incident: Taking Advantage of the Current Climate of Change in Nuclear Regulation

Although nothing is certain, it is not too far-fetched that, should fusion become a major player in U.S. energy infrastructure, a nuclear incident under the PAA might

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[222] *See supra* notes 199–203 and accompanying text.

eventually be alleged. It is also possible that even before then, a claim could arise if an incident occurred at a research facility. If such an incident were to occur, it is also likely that the defendant plant operator might wish to remove the action to federal court via the PAA's public liability action mechanism.

Knowing that ambiguities exist in the language may not itself be sufficient to go back and revise the PAA's language. However, in the past few years, there has been considerable movement and Congressional desire to revisit, reevaluate, and streamline the otherwise stale state of nuclear regulation. The Nuclear Energy Innovation and Modernization Act (NEIMA), passed in 2019, specifically directed the NRC to "complete a rulemaking to establish a technology-inclusive, regulatory framework for optional use by commercial advanced nuclear reactor applicants for new reactor license applications"[223] by the end of 2027, with fusion reactors specifically included under the umbrella of "advanced nuclear reactor."[224] The cited NRC efforts regarding fusion regulation within the past year, which continue work that began in earnest in 2009,[225] have been in part due to this mandate.[226] The more significant effort in response to the mandate is the development of an additional framework to license advanced reactors, known as the "Part 53" framework.[227] While Part 53 is being built in anticipation of advanced fission-based reactors, it is not necessarily exclusive to fusion reactors.[228]

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[223] Nuclear Energy Innovation and Modernization Act, Pub. L. 115-439 § 103 (a)(2)(B)(4) (115th Cong. 2019).

[224] *Id.* § 3(1).

[225] Memorandum from R.W. Borchardt, Exec. Dir. for Operations, NRC, to the Commissioners, SECY-09-0064 Regulation of Fusion-Based Power Generation Devices (Apr. 20, 2009), https://www.nrc.gov/docs/ML0922/ML092230171.pdf ") [hereinafter SECY-09-0064] [https://perma.cc/UL5E-YBF4].

[226] NRC FUSION MEMORANDUM, *supra* note 2, at 2.

[227] Nuclear Regul. Comm'n, *Part 53—Risk Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors*, https://www.nrc.gov/reactors/new-reactors/advanced/rulemaking-and-guidance/part-53.html (Nov. 20, 2023) (detailing the Part 53 efforts to date) [https://perma.cc/FMQ7-BY4E].

[228] *Id.*

Climate change and energy security have motivated additional support for the nuclear power industry in the years since NEIMA including support for the development of advanced technologies and the role of nuclear power in energy infrastructure in the Energy Act of 2020, the Infrastructure Investment and Jobs Act of 2021, and the Inflation Reduction Act of 2022. The resultant support for the modernization of the nuclear regulatory structure and interest in promoting the development of nuclear energy presents a natural opportunity to critically consider fusion's place within the PAA public liability scheme well before an incident might occur and thus be left solely to judicial interpretation. There exist at least two avenues the NRC or Congress could pursue to better clarify the discussed ambiguities regarding fusion that may arise in case of an incident: 1) the NRC expressly defining fusion products as part of a material subset under its Congressionally-granted discretion and 2) Congress amending the PAA or pertinent definitions of the AEA as part of the upcoming choice to renew the indemnification provisions of the PAA by 2025.

1. Why the PAA Public Liability Provisions Matter for Fusion

Under current and proposed schemes, with fusion technologies being regulated indirectly as users of byproduct material, fusion power plants would optionally be required to "have and maintain financial protection" at the discretion of the NRC.[229] With respect to NRC licensees, the NRC "shall" agree to indemnify those licenses for which it requires insurance of less than $560 million from public liability exceeding that of the required financial protection—but *only* for those public liability actions *arising from nuclear incidents*.[230] Although public liability actions themselves include legal liability resulting

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[229] 42 U.S.C. § 2210(a). Utilization and production facilities require financial protection. Research and development facilities, as well as byproduct material, use facilities that optionally require protection at the discretion of the NRC.

[230] 42 U.S.C. § 2210(c).

from precautionary evacuations,[231] limitations on overall public liability are also only applicable for public liability arising from a nuclear incident, as are the removal provisions for public liability actions.[232] The limitation provision is also only specified for "persons indemnified."[233]

A failure to include fusion as part of PAA public liability actions, primarily through ambiguity in whether an incident at a plant falls under the scope of a "nuclear incident," creates three issues. First, fusion plants are not protected by excess aggregate public liability unless the incident is a nuclear incident. While it is impossible to speculate on what the cleanup cost would truly be without detailed models of contamination, the cost of cleanup from the Three Mile Island incident in 1979—which resulted in no attributable deaths or cancer[234]—was estimated to be over $1 billion by the end of cleanup efforts in 1993.[235] The PAA aggregate liability limit also includes the cost of legal expenses resulting from lawsuits.[236] Such costs could readily accrue if the litigation from an accident continues for decades, as it did for Three Mile Island.[237]

Second, if the aggregate liability limit is exceeded, the public nonetheless has assurance that it will be compensated through the PAA's mechanism to provide "full and prompt compensation to the public" for such public liability claims arising from a nuclear incident.[238] If a court determines that an incident is *not* a nuclear incident in the context of an event at a fusion plant, the public faces no backup allocation of funds if the incident

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[231] *Id.*

[232] *Id.* §§ 2210(e), (n)(2).

[233] *Id.* § 2210(e).

[234] *Three Mile Island Accident*, WORLD NUCLEAR ASS'N (Apr. 2022), https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx [https://perma.cc/C322-WWUM].

[235] *14-Year Cleanup at Three Mile Island Concludes*, N.Y. TIMES (Aug. 15, 1993), https://www.nytimes.com/1993/08/15/us/14-year-cleanup-at-three-mile-island-concludes.html [https://perma.cc/W8CJ-R5V].

[236] 42 U.S.C. § 2210(e).

[237] *Backgrounder on Nuclear Insurance and Disaster Relief*, NUCLEAR REGUL. COMM'N (Apr. 2022), https://www.nrc.gov/docs/ML0327/ML032730606.pdf [https://perma.cc/M94T-7CPM].

[238] 42 U.S.C. § 2210(e)(2).

plant is unable to provide mandated relief. Clearly determining that fusion plants fall under the PAA's public liability scope provides this assurance to the public.

Finally, removal does not only benefit defendant plants, but also the public at large, by providing a predictable forum for hearing PAA claims. The 1988 Amendments to the PAA, providing for federal jurisdiction over public liability actions in the district where a nuclear incident occurs, came in the midst of hearing hundreds of claims raised in response to the Three Mile Island incident. Furthermore, the federal removal mechanism provides not only a straightforward consolidation mechanism, but also the appointment of a "special caseload management panel" to manage case consolidation and the establishment of claim priority, case assignment, and other measures to aid in expediting the hearing of claims.[239] Taken as a whole, the removal provisions provide for the more consistent and more efficient hearing of cases involving nuclear events, which would serve the interest of the fusion industry if such an event were to arise.

2. Option 1: Defining Fusion Products as a Material Subset in NRC Rules

Since a "nuclear incident" for the purposes of the PAA is defined to arise out of or result from "radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material,"[240] defining fusion fuels and products as one of the three enumerated materials would bring fusion plants under the umbrella of the PAA. The NRC has limited authority to define materials as any of these three types as part of its rulemaking without the need for statutory changes.

The NRC is delegated express authority to determine if materials other than those enumerated in the AEA are source material or special nuclear material.[241]

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[239] *Id.* § 2210(n)(3).

[240] *Id.* § 2014(q).

[241] *Id.* § 2014(e).

One such delegation includes designating material as a byproduct material—for materials presenting a similar risk to that posed by radium-226—but such designation requires a consensus with other federal agencies.[242] Should a material be designated as a special nuclear material, however, any radioactive material "yielded in or made radioactive by" processes making use of or producing special nuclear material would qualify as byproduct material.[243]

The delegated authority is not without limits. To include new materials under the "special nuclear material" umbrella, the NRC must find specifically that "such material is capable of releasing substantial quantities of atomic energy" and its determination as special nuclear material must be "in the interest of the common defense and security."[244] Such determination also requires agreement of the President.[245] For source material, the material must be "essential to the production of special nuclear material," along with the "common defense and security" and Presidential agreement criteria.[246]

Taken together, then, the definition of "special nuclear material" emerges as the most influential term of the three—defining a material as special nuclear material influences both the definitions of source material and byproduct material. The definition of special nuclear material is dependent on the definition of "atomic energy," warranting some brief discussion on whether fusion energy is "atomic energy" in the context of the AEA. The question arises particularly because the definition of "atomic energy" in the AEA is "all forms of energy released in the course of nuclear fission or nuclear transformation," with fusion bearing no mention.[247]

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[242] *Id.*
[243] *Id.* § 2014(e)(1).
[244] 42 U.S.C. § 2071.
[245] *Id.*
[246] *Id.* § 2091.
[247] *Id.* § 2014(c).

It was known to legislators at the time that nuclear fusion was a distinct nuclear process,[248] so it is not that nuclear fusion was simply omitted out of ignorance. There exists legislative history evidence that fusion is intended to be included in the term "nuclear transformation." The proponents of the Atomic Energy Act of 1954 expressly amended the original Atomic Energy Act of 1946 to replace the term "fissionable material" with "special material"[249] to indicate a broadening of the scope of the AEA's coverage.[250] In justifying this change, the chairmen specifically mentioned that material "utilizable in a fusion process" fell under the scope of "special material."[251] The final report of the Joint Committee on Atomic Energy for the AEA also indicated that the definition of "atomic energy" was meant to encompass both fission and fusion.[252] The NRC has cited such legislative history as evidence that, as a general matter, it has jurisdiction over the regulation of fusion power facilities and therefore possible authority to regulate fusion devices as utilization facilities.[253]

Any interpretation of inclusion of fusion materials under the "special nuclear material" umbrella, however, is just that—an interpretation. Should the NRC include fusion materials under the definition, it would be vulnerable to interpretive challenges. Despite the

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[248] *S. 3323 and H. R. 8862, to Amend the Atomic Energy Act of 1946: Hearings Before the Joint Committee on Atomic Energy*, 83rd Cong. (1954), Vols. I and II 14 (Joint Statement of Chairman Cole and Vice Chairman Hickenlooper of the Joint Committee on Atomic Energy) (making specific reference to the "fusion process" when discussing the types of reactions).

[249] *Id.* Note that the phrase used in the statement of the Chairmen was, in fact, "special material," not "special nuclear material," although the latter was what was in the Act.

[250] *Id.*

[251] *Id.*

[252] S. REP. NO. 83-1699, at 8, 11 (1954), *as reprinted in* 1954 U.S.C.C.A.N. 3456, 3464, 3466.

[253] SECY-09-0064, *supra* note 225 (citing the Committee Report as justification to include fusion plants as "utilization facilities" that make use of "atomic energy"); Memorandum from Annette L. Vietti-Cook, Sec'y, NRC, to R.W. Borchardt, Exec. Dir. for Operations, NRC, Staff Requirements – SECY-09-0064 – Regulation of Fusion-Based Power Generation Devices (July 16, 2009), https://www.nrc.gov/docs/ML0922/ML092230198.pdf (indicating the Commissioners' intent to presume jurisdiction over fusion plants under this analysis) [https://perma.cc/YT63-577N]; NRC FUSION MEMORANDUM, *supra* note 2, at 8.

legislative history indicating a desire to include fusion as a form of atomic energy, it is not actually in the statute. If the chairmen intended for fusion to fall within the AEA's scope, why not just include it outright? Such an omission leaves the interpretation that "transformation" necessarily includes "fusion" vulnerable to analysis under textualist interpretation canons such as *expressio unius* (considering that the "expression of one thing implies the exclusion of others"[254]) and the omitted-case canon (considering that "a matter not covered is to be treated as not covered"[255]).

One plain dictionary definition of "transformation" is "an act, process, or instance of transforming or being transformed."[256] This, in and of itself, is not particularly informative. However, the argument could be made that the common meaning of "transformed" is "changed," which may encompass fusion. Leading nuclear engineering textbooks are inconsistent, some using the term "transformation" to refer to nuclear decay alone, not even considering fission reactions in the same context, and others referring to fusion reactions specifically as "transformations."[257]

Regardless of where a textual interpretation or a legislative intent might lead, the inclusion of fusion materials as "special nuclear material" also introduces an entanglement with the definitions of "utilization facility" and "production facility." The NRC definitions of such facilities might capture fusion plants as-is. If fusion fuels, such as tritium, were included in the definition of special nuclear material, it could be argued that fusion plants are "accelerator-driven subcritical operating assembl[ies] used

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[254] SCALIA & GARNER, *supra* note 210, at 107.

[255] *Id.* at 93.

[256] *Transformation*, MERRIAM-WEBSTER, https://www.merriam-webster.com/dictionary/transformation (last updated Nov. 17, 2023) [https://perma.cc/69C4-6YUJ].

[257] *Compare* LAMARSH & BARATTA, *supra* note 22, at 20 (using "transformation" in the context of nuclear decay chains, and nowhere else in the text, except with reference to chemical reactions), *with* J. KENNETH SHULTIS & RICHARD E. FAW, FUNDAMENTALS OF NUCLEAR SCIENCE AND ENGINEERING 116 (2002) (using "transformation" and "transformed" in describing the fusion of four hydrogen atoms to a helium atom and two beta particles).

for the irradiation of materials containing special nuclear material,"[258] which would make them a utilization facility. If the resultant neutrons and other products of fusion were considered special nuclear material, it could be argued that fusion plants "process[] . . . irradiated materials containing special nuclear material,"[259] making them production facilities. The arguments used to justify inclusion of fusion fuels in the first place, involving interpretation of "atomic energy," would further implicate statutory definitions in the AEA.[260] Although courts have shown great deference to what the NRC considers utilization facilities, this nonetheless introduces additional complexity and dependency to the definitions which may not be desired from either a regulatory or a policy standpoint.

Since source material is defined based on its derivation from special nuclear material and is thus directly dependent on the definition of special nuclear material, making use of NRC authority to define "source material" would not be fruitful. Although the NRC is expressly delegated authority to define special nuclear material and source material, it is *not* granted the same authority to define byproduct material. Thus, inclusion of fusion fuels and products as byproduct material is wholly dependent on the success of the NRC's ability to include such materials as byproducts of particle accelerators. As described above, however, the NRC's interpretation of either the Congressional meaning of "particle accelerator" or its interpretations of its own rule implementing what defines a particle accelerator are vulnerable to judicial challenge.

It should be noted that a natural thought would be to somehow include fusion fuels and products as a part of Part 53 or other fusion rulemaking. However, the key definition at play—"nuclear incident"—is statutorily defined in the AEA, and Congress has granted no authority to the NRC to modify it. Therefore, the only avenue for the

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[258] 10 C.F.R. § 50.2 (2015).

[259] *Id.*

[260] 42 U.S.C. § 2014(c).

NRC to include fusion fuels and products under the PAA with the delegatory tools it has at its disposal is through its authority to define the contours of the materials definitions alone. Furthermore, although the NRC has historically enjoyed a great amount of deference from the courts in its interpretation of AEA provisions, such deference could cease at any time, especially in light of increased scrutiny of *Chevron*.[261] While express authority has been granted to the NRC for some materials definitions, there is nonetheless some legislative interpretation required, leaving any interpretation possibly open to judicial review and more protracted litigation.

3. Option 2: Congressionally Amending the PAA-Related Provisions of the AEA as Part of the 2025 Choice to Renew

The Energy Policy Act of 2005 included the Price-Anderson Amendments Act of 2005.[262] Among other provisions, the Act extended the PAA's indemnification provisions until 2025, modifying insurance premium maxima and other liability limits, clarifying the treatment of facilities with multiple small modular reactors, and limiting penalties that can be levied against nonprofit entities.[263] Unless Congress opts to renew the indemnification provisions in 2025, they will lapse, and new licensees and contractors will not be covered by PAA indemnification.[264] As part of the Act, both the NRC and

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[261] *E.g.*, Jackson Nichols, *Chevron's Watery Grave?*, REGUL. REV. (June 20, 2023), https://www.theregreview.org/2023/06/20/nichols-chevrons-watery-grave/ [https://perma.cc/83Z2-DN3K].

[262] Energy Policy Act of 2005, Pub. L. 109-58, §§ 601–610, 119 Stat 594.

[263] *Id.*

[264] There was a failed effort in 2001 to extend all dates beyond the August 2002 expiration granted by the 1988 Amendments through 2017. H.R. 2983, 107th Cong. (2001). Some were subsequently extended through 2005 in various other acts prior to the 2005 extension, while others were briefly extended, but not through 2005, and were not extended at all. *Compare* Bob Stump National Defense Authorization Act for Fiscal Year 2003, Pub. L. 107-314, § 3172, 116 Stat 2458 (extending indemnification for DOE contractors until the end of 2005) *and* Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005, Pub. L. 108-375, § 3141, 118 Stat 1811 (same,

the DOE were required to submit reports regarding the "need for continuation or modification of the provisions"[265] of the PAA; both entities recommended the PAA's continuance in their respective reports.[266]

Since the PAA indemnification provisions will not continue without express Congressional action, it is natural to assume that Congress will need to pass an act akin to the Price-Anderson Amendments Act of 2005 (likely as part of more omnibus legislation but pass nonetheless) if it takes the recommendations of the NRC and DOE to heart.[267] Such legislation will need to be passed before the 2025 expiration date for any new NRC licensees to receive the benefits of indemnification. With nearly a dozen advanced reactor applicants presently engaged in pre-application review,[268] it is possible that several would fall outside of the end-of-2025 window for indemnification by the time the licensing process ends. Congress would thus be incentivized to renew the indemnification provisions of the PAA within the next eighteen months to ensure that advanced reactor applicants are further motivated to begin the licensing process with the NRC.

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until the end of 2006) *with* Pub. L. 109-58, §§ 602(a)(2), (c) (indicating that the indemnification provisions for NRC licensees and non-profits were not extended through the time of the Energy Policy Act of 2005, with the former having been extended once from August 2002 to the end of 2003 in Pub. L. 108-7, Div. O § 101).

[265] Pub. L. 109-58 at § 606 (codified at 42 U.S.C. § 2210(p)).

[266] ARCENEAUX ET AL., *supra* note 8, at xxiv; *see* U.S. DEP'T OF ENERGY, PRICE-ANDERSON ACT: REPORT TO CONGRESS iii (2023), https://energy.gov/sites/default/files/2023-02/PAA%20Report%20January%202023_0.pdf [https://perma.cc/QT8X-6AJG].

[267] At the time of publication (December 2023), the current Congress did indeed consider extending the PAA as a part of omnibus legislation in the Defense Authorization Act (NDAA) for Fiscal Year 2024. The Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act, included in the 2024 NDAA version passed by the Senate, would have extended the PAA to 2045. The ADVANCE Act was struck, however, upon consideration by the House. Compare S. 2226, 118th Cong. at 1724–25 (as engrossed in Senate, July 27, 2023) (containing the ADVANCE Act, with the PAA extension at pages 1724-25), with H.R. REP. NO. 118-301 (2023) (Conf. Rep.) (omitting the ADVANCE Act). The Atomic Energy Advancement Act was subsequently introduced in response on December 1, 2023; in its initial version, it proposes extending the PAA to 2065. H.R. 6544, 118th Cong. (2023).

[268] *Pre-Application Activities for Advanced Reactors*, NUCLEAR REGUL. COMM'N, https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities.html (Nov. 3, 2023) [https://perma.cc/BAJ8-NSLH].

Such a renewal of the PAA indemnification provisions provides a natural point for Congress to also consider how fusion plants, fuels, and products should fit into the PAA public liability scheme. A review of PAA provisions in 2025 would also fit the roughly 20-year review cycle currently in place, with the 2005 amendments coming seventeen years after the 1988 amendments. Review of the Act beyond the indemnification provisions would also not necessarily fall outside of scope. The Amendments Act of 2005 included a provision ("Treatment of Modular Reactors") specific to the possibility of a facility comprised of multiple smaller modular reactors producing the same power output as a single-reactor facility.[269] No such facilities existed at the time, and indeed, no such facilities exist today, with the first small modular reactor design receiving NRC design certification just this year.[270] There is thus precedent for Congressional PAA-amending acts to proactively address possible shortcomings of the PAA's verbiage for future, as-yet-unrealized reactor designs.

In NEIMA, Congress elected to allow the NRC to determine how to best regulate future fusion reactors, although Congress itself certainly has the authority to define fusion reactors as either "utilization facilities" or their products as "byproduct material" without leaving it to the NRC's contemplation.[271] The lack of absolute direction suggests that Congress intended to leave the matter broadly to the NRC's expertise. Indeed, the scope of NEIMA's delegation was not a point of particular contention in NEIMA's hearings, with language primarily couched in the context of supporting the creation of

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[269] Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 608.

[270] NuScale Small Modular Reactor Design Certification, 88 Fed. Reg. 3287 (Jan. 19, 2023).

[271] The NRC has considered both of these pathways as fusion regulation options. NUCLEAR REGUL. COMM'N, *supra* note 213, at 2.

appropriate regulatory frameworks, not statutory directives.[272]

Thus, should Congress elect to clarify the coverage of fusion devices under the PAA public liability frameworks, it should be mindful of the implications that any statutory definitions carry. For example, electing to add fusion products to the definition of special nuclear material would constrain the NRC to regulating fusion plants as utilization facilities, and adding fusion fuels and products to byproduct material would constrain the NRC to working within the byproduct materials framework. Not only would this make much of the NRC's efforts to regulate fusion moot, it would also run counter to the deference given to the NRC in NEIMA. Although Congress could define fusion fuels and products based on the current trends in NRC staff thinking, the NRC's current rulemaking proposals nonetheless seek flexibility in their implementation, as the configuration and form of future high-output fusion plants are still unknown. Although it would be within Congress's purview to define fusion fuels and products within the materials frameworks to resolve the PAA ambiguity, it would need to be done with considerable care as it would have further-reaching effects beyond the scope of the PAA.

Some definitions could bring overall clarity, such as expressly including fusion reactions in the definition of "atomic energy," but would not necessarily provide clarity within the context of the PAA. Alternatively, Congress could define a new materials category, which would resolve some of the interpretive issues with defining fusion plants as "particle accelerators." The most direct way to encompass fusion plants under the PAA public liability provisions is to include them in the enumerated list of qualifying materials for "nuclear incident." Although they could be included as part of the qualifying events for "public liability," as "precautionary evacuations" are, most

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[272] *See generally Hearing on S.512, The Nuclear Energy Innovation and Modernization Act: Hearing Before the Comm. on Env't and Pub. Works*, 115th Cong. (2017).

of the protections inherent in the public liability classification (such as the limitation on aggregate liability and the removal action) are limited in the text to public liability relating to nuclear incidents.

Direct inclusion in the list of qualifying events for "nuclear incidents" without addressing other AEA or PAA dependencies, however, could introduce inconsistencies in an otherwise cohesive scheme. It could be that Congress is simply willing to allow the ambiguities, particularly in the interpretation of "byproduct material," to remain until the NRC finalizes its fusion rules or until an incident arises. But inclusion of fusion plant fuels and products, even as a stopgap, could stay ahead of any issues brought before NRC licensing, since NEIMA does not require any regulatory scheme until 2027. A careful examination of the requisite definitions in the AEA itself, alongside thoughtful coordination with the NRC as it builds its regulatory suite for fusion plants, could follow. Congress could also take a deeper look into how current AEA definitions present difficulty for the NRC to meet its statutory mandate to develop a licensing scheme for advanced nuclear reactors. Updating provisions that directly or indirectly implicate the PAA would provide additional overall clarity for regulation of the future nuclear sector.

In any case, the desire to support fusion energy as part of the future of the U.S. energy grid is apparent at this current moment in the face of climate change and reduced energy security. Fusion energy would prove revolutionary in both regards, and a forward-thinking Congress could allow for much easier entry of fusion into the energy space.

CONCLUSION

Although fatalism and catastrophizing are not productive within the nuclear space, it is well within the realm of possibility that future fusion plants (or even those currently under development) will be subject to a PAA public liability lawsuit. Such an event need not necessarily be as catastrophic as the theorized accident here, or that of Three Mile Island, but more akin to the smaller-scale incidents seen throughout the history of PAA public liability actions. Should an event arise, regardless of scope, there is currently ambiguity as to whether PAA public liability provisions apply to fusion plants.

While the ambiguities could be left to courts to resolve, it would be more prudent to address them well before an incident arises. The decision of Congress to extend the indemnification provisions of the PAA, ideally within the next eighteen months before the provisions expire in 2025, provides a natural venue for Congress to do so without leaving it to the interpretive whim of the NRC. Although the NRC has opted to regulate near-future fusion plants under existing materials licensing schemes, it has already identified difficulties in fitting fusion plants into the current congressional delegations of authority, requiring extensive interpretation on behalf of the agency and issuance of guidance which may be vulnerable to judicial review.

Regardless, the key public liability provisions of the PAA at issue are not delegated. Choosing to clarify fusion's role in the PAA public liability scheme provides reassurance of compensation to the public in case of an incident, offers incentives to enter the industry, and would expedite any litigation that may arise from an incident. Such clarification is not outside the scope of previous PAA amendments, and Congress should take note to consider such clarifications to the PAA public liability provisions in the 2025 choice to renew the PAA indemnification provisions.