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Regulation, Radiation, and Rationality: Calculating an Intersection of Law and Economics to Enable Nuclear Power Innovation in the United States

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I. INTRODUCTION

"Nuclear power is one hell of a way to boil water,"[1] according to Karl Grossman in 1980, and many people across the world today would likely agree. But how should the United States think about its use of nuclear energy?

Modern dialogue concerning the energy sector has been increasingly influenced by the pressing concerns of climate change. In the U.S., President Joe Biden devoted a significant portion of his 2020 campaign efforts to making promises about addressing the climate crisis, and he has followed through with those assurances thus far by rejoining the Paris Agreement and creating the National Climate Task Force.[2] The goals of the Task Force include reducing U.S. greenhouse gas emissions to 50-52% below 2005 levels by 2030, reaching 100% carbon pollution-free electricity by 2035, and achieving a net-zero emissions economy by 2050.[3]

To this end, Congress passed the Infrastructure Investment and Jobs Act in 2021, which appropriated and authorized funding to sustain the existing nuclear fleet in the U.S. and to support the development and commercialization of advanced nuclear power.[4] In April 2022, as part of the government's efforts to reduce climate impact and transition to sustainable energy supplies, the Biden administration opened applications for a six billion dollar program to support struggling nuclear power plants.[5] The Department of Energy reports that the U.S. nuclear industry's reactors generate more than half of the country's carbon-free electricity.[6] However, nuclear electric power accounted for only 8% of the country's primary energy production in 2021, as it was outpaced by production of coal (11%), crude oil (23%), and natural gas (35%).[7] In 2020, fossil fuels (natural gas, coal, petroleum, and other gasses) supplied 60.8% of the country's total electricity, whereas nuclear power

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[1] KARL GROSSMAN, COVER UP: WHAT YOU ARE NOT SUPPOSED TO KNOW ABOUT NUCLEAR POWER 155 (Franklin Watts ed. 1980).
[2] *National Climate Task Force: President Biden's Actions to Tackle the Climate Crisis,* THE WHITE HOUSE, https://www.whitehouse.gov/climate/, [https://perma.cc/L2V7-EQ8Y] (last visited November 7, 2022).
[3] *See id.*
[4] Grant Dever, *Nuclear energy is infrastructure*, OPPBLOG (December 16, 2021), https://blog.freopp.org/nuclear-energy-is-infrastructure/, [https://perma.cc/FJK8-KBM4].
[5] Timothy Gardner, *Biden administration launches $6 bln nuclear power credit program*, REUTERS (April 20, 2022), https://www.reuters.com/world/us/biden-admin-launches-6-bln-nuclear-power-credit-program-2022-04-20/, [https://perma.cc/G8T4-QNM6].
[6] *See id.*
[7] *US Energy Facts Explained*, U.S. ENERGY INFO. ADMIN. (Last updated June 10, 2022), https://www.eia.gov/energyexplained/us-energy-facts/, [https://perma.cc/YQ5H-RKEQ].

provided only 18.9%.[8] This is an unfortunate distribution given that energy-related greenhouse gas emissions account for the majority of anthropogenic emissions globally, and the generation of electricity accounts for over 40% of all energy-related emissions.[9] The U.S. is the second largest greenhouse gas emitter in the world, and with energy demand growing, its carbon dioxide emissions are expected to continue to rise, with the electric power sector continuing to be the largest emitter.[10]

Yet here has been a resurging interest in nuclear power because of its potential to address energy security and climate change, despite lingering consternation over waste management and economic costs.[11] Although no new U.S. reactors had been approved since 1978, the U.S. began actively collaborating with nine other countries in 2007 to develop fourth-generation reactors in hopes of creating safer, lower-cost, and lower-risk technology.[12] That innovative effort has continued to the present day.[13] Yet despite current worldwide trends toward greater use of nuclear power,[14] some fear that the current federal regulations in the U.S. have been a hinderance to the nuclear industry, and that the strict system will prevent any further progress.[15] Outside of that specific consideration,

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[8] *Frequently Asked Questions,* U.S. ENERGY INFO. ADMIN. (last updated March 4, 2022), https://www.eia.gov/tools/faqs/faq.php?id=427&t=3 [https://perma.cc/QH9L-DMAD].

[9] *Carbon Dioxide Emissions from Electricity*, WORLD NUCLEAR ASS'N (last updated October 2022), https://www.world-nuclear.org/information-library/energy-and-the-environment/carbon-dioxide-emissions-from-electricity.aspx#:~:text=Over%2040%25%20of%20energy%2Drelated,not%20produce%20any%20CO2, [https://perma.cc/C3KP-QHYY].

[10] Robert K. Dixon, Elizabeth McGowan, Ganna Onysko & Richard M. Scheer, *US energy conservation and efficiency policies: Challenges and opportunities*, ENERGY POLICY, VOLUME 38, ISSUE 11, 2010, Pages 6398-6408 https://doi.org/10.1016/j.enpol.2010.01.038.

[11] Nathan Hultman, Jonathan Koomey & Daniel Kammen, *What History Can Teach Us about the Future Costs of U.S. Nuclear Power*, AM. CHEM. SOC'Y (April 1, 2007), pg. 2089.

[12] *See id.* at 2088.

[13] *Bilateral Cooperation*, OFF. OF NUCLEAR ENERGY, https://www.energy.gov/ne/bilateral-cooperation [https://perma.cc/R8BH-LQZ7].

[14] For examples of this trend, *see* Robert Rapier, *Nuclear Power's Future Is Looking Brighter,* FORBES (Feb. 13, 2022), https://www.forbes.com/sites/rrapier/2022/02/13/nuclear-powers-future-is-looking-brighter/?sh=62b7ebe72f0d [https://perma.cc/Z993-3QAQ].

[15] For discussion of the impact of current and historical regulations on the nuclear power industry, *see generally* Grant Dever, *The Urgency of Rethinking U.S. Nuclear Energy Regulation*, FREOPP (July 30, 2022), https://freopp.org/rethinking-u-s-nuclear-energy-regulation-7639c7e88642 [https://perma.cc/ETX5-737V]; for perspectives on the need for and optimal paths for nuclear regulatory reform, *see generally* E. Ray Canterbery et al, *Cost Savings from Nuclear Regulatory Reform: An Econometric Model,* 62 SOUTHERN ECONOMIC JOURNAL 554, (https://doi.org/10.2307/1060879); and for discussion of nuclear regulatory reform and the need for public involvement, *see* Richard Goldsmith, *Regulatory Reform and the Revival of Nuclear Power*, 20 HOFSTRA L. REV. 159 (1991).

there has been scholarly concern over whether regulation in general may inherently create barriers to innovation.[16]

In order to effectively respond the issues presented by worsening climate change, coupled with the increasing price volatility of common energy sources and the unpredictability of their supply chains, the U.S. must formalize future energy strategies that are both ecologically and economically sustainable as quickly as possible.[17] Nuclear power, although historically subject to much scrutiny and fear, has vast potential to fulfill that goal.[18] However, I assert that the current regulatory scheme, which addresses nuclear power plants solely through a lens of prevention and backfitting,[19] cannot account for the reality of the incentives in the nuclear power industry; cannot provide adequate remedies when harms do occur; and cannot spur the kind of innovation that will lead to safer, more efficient reactors. Therefore, the U.S. must urgently assess its regulatory approach to nuclear power plants in order to secure its energy future through this promising technology.

Despite the familiarity of regulation and the sense of security it can bring, I propose the U.S. should utilize economic incentives and tools, such as private insurance, consumer-company negotiations, and catastrophe bonds, as the foremost hedge against the risks of nuclear power plants. Negotiation between nuclear power providers and consumers should be one elective option for remediation of risk and potential damages, and common law torts should be the foundation of the remedy for injured persons who have agreed to forgo advance incentives like reduced pricing for electricity.

This article will first present background information on the U.S. energy sector, the general use of green energy and the impacts of that technology, and the history of nuclear power, both globally and

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[16] For discussion about technological innovation and regulations, *see generally* Mark Fenwick, Wulf A. Kaal & Erik P. M. Vermeulen*, Regulation Tomorrow: What Happens When Technology Is Faster than the Law*, 6 AM. U. BUS. L. REV. 561 (2017); for discussion of market forces, innovation, and regulation, *see generally* Yafit Lev-Aretz & Katherine J. Strandburg, *Regulation and Innovation: Approaching Market Failure from Both Sides,* 38 JREG BULLETIN 1 (2020-2021); for discussion of the interplay between innovation, market forces, and regulation, *see generally* Richard B. Stewart, *Regulation, Innovation, and Administrative Law: A Conceptual Framework*, 69 CALIF. L. REV. 1256 (1981).

[17] For discussion of the volatility of electricity, *see generally* Carlo Mari, *Hedging electricity price volatility using nuclear power*, 113 APPLIED ENERGY 615 (2014), https://doi.org/10.1016/j.apenergy.2013.08.016 [https://perma.cc/HQW3-2QEW].

[18] *See* Rapier, *supra* note 14.

[19] Backfitting occurs when new or changed regulatory requirements or interpretations are imposed on nuclear power reactor licensees, nuclear power reactor applicants, or nuclear materials licensees. *See* 10 CFR §50.109.

domestically. A discussion of current regulatory circumstances in the U.S. will follow. I will next propose several facets of the approach that I believe can enable a prosperous future for the nuclear industry and the U.S. as an energy consumer. I will elaborate upon the ideas of economics and insurance, the ideal judicial approach, and the possible role of the federal government. To conclude, I will address common concerns about nuclear power.

II. A PRIMER ON ENERGY

A. An Evolving Field

The energy sector in the U.S. is comprised of a diverse mix of resources and technologies, ranging from historically common sources, such as coal and petroleum, to newer, green generators like biomass energy.[20] For decades, fossil fuels have been the dominant energy source for the country, but the use proprtions within that category have changed over time. For example, coal consumption and production has decreased since 2008, whereas production of natural gas reached a new peak in 2021—a development which has reduced consumption costs and led to increased reliance on it as a source for electricity.[21] As for renewable energy, both production and consumption reached record highs in 2021, primarily driven by solar and wind power sources.[22] For several decades, reducing pollution and preserving environmental quality have been federal interests as well as social concerns, evidenced by the passing of the Clean Air Act in 1970;[23] the Clean Water Act in 1972;[24] the Resource Conservation and Recovery Act in 1976;[25] the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980;[26] and the Energy Independence and Security Act in 2007.[27]

These facts indicate general awareness that environmental degradation is a serious problem, and there are several points that must be addressed to find a sustainable solution to that quandary. One piece of

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[20] *See* ENERGY INFO., *supra* note 7.
[21] *See id.*
[22] *See id.*
[23] 42 U.S.C. §7401 *et seq.* (1970).
[24] 33 U.S.C. §1251 *et seq.* (1972).
[25] 42 U.S.C. §6901 *et seq.* (1976).
[26] *Summary of the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund),* U.S. ENV'T PROT. AGENCY (last updated September 12, 2022), https://www.epa.gov/laws-regulations/summary-comprehensive-environmental-response-compensation-and-liability-act [https://perma.cc/VV23-WBB3]; 42 U.S.C. §9601 et seq. (1980).
[27] *Summary of the Energy Independence and Security Act,* U.S. ENV'T PROT. AGENCY (last updated May 12, 2022), https://www.epa.gov/laws-regulations/summary-energy-independence-and-security-act [https://perma.cc/T5KZ-CBJS].

the discussion for crafting a sustainable scheme for production and consumption is potential changes in the elasticities of energy supplies and variations in demand by climate region.[28] It is also critical to recognize the current damaging impacts and risks of common and emerging energy sources.

Coal has a deeply detrimental impact on the environment. In a 1978 paper, the Oak Ridge National Laboratory concluded that the waste produced by coal plants is more radioactive than the waste generated by nuclear power plants; specifically, fly ash—a byproduct from burning coal for electricity—exposes the environment to 100 times more radiation than a nuclear power plant producing the same amount of energy.[29] Ounce for ounce, coal ash from a power plant delivers more radiation than water or dry cask-shielded nuclear waste.[30] Coal plants also emit greenhouse gases.[31] Ultimately, despite their high energy production capacity, coal plants are directly linked to increased morbidity, mortality, and land disturbance.[32]

Although emissions from the combustion of natural gas are lower than those from coal or oil, natural gas is still a fossil fuel that emits harmful levels of carbon dioxide.[33] Additionally, the methane release from drilling, extraction, and transportation contributes to trapped heat even more than carbon dioxide does.[34] Furthermore, although natural gas burns cleaner than other fossil fuels, there is a risk of local and regional air quality deterioration in drilling areas, with air pollutants potentially

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[28] *See* Erin T. Mansur, Robert Mendelsohn & Wendy Morrison, *Climate change adaptation: A study of fuel choice and consumption in the US energy sector,* 55 JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT 175 (2008), (https://doi.org/10.1016/j.jeem.2007.10.001).

[29] Mara Hvistendahl, *Coal Ash Is More Radioactive Than Nuclear Waste*, SCI. AM. (December 13, 2007), https://www.scientificamerican.com/article/coal-ash-is-more-radioactive-than-nuclear-waste/ [https://perma.cc/ZP8Z-JTMW].

[30] *See id.* On this point, it is useful to note the distinction: the nuclear waste in this comparison has containment measures, whereas the coal waste does not. However, this detail is not so much cause to dismiss the statistic as it is a reason to contemplate why the U.S. permits flagrant emissions from coal plants and to think critically about our framework for assessing risk.

[31] See B.D. Hong & E. R. Slatick, *Carbon Dioxide Emission Factors for Coal*, Quarterly Coal Report, January-April*,* ENERGY INFO. ADMIN. 1 (1994), (https://www.eia.gov/coal/production/quarterly/co2_article/co2.html).

[32] Alexander Zerrahn, *Wind Power and Externalities*, 141 ECOLOGICAL ECONOMICS 245, 249 (2017), (https://doi.org/10.1016/j.ecolecon.2017.02.016).

[33] *Environmental Impacts of Natural Gas,* UNION OF CONCERNED SCIENTISTS (June 19, 2014), https://www.ucsusa.org/resources/environmental-impacts-natural-gas#:~:text=Natural%20gas%20is%20a%20fossil,new%20coal%20plant%20%5B1%5D [https://perma.cc/A62S-5ZMV].

[34] *See id.*

leading to adverse health outcomes such as respiratory ailments and cancer.[35]

Green energy sources admittedly have fewer risks and negative impacts than traditional sources. Two notable energy sources are wind power and hydropower. Wind power has substantially lower emissions, lower human health impacts, and lower accident risk;[36] hydropower plants produce no direct waste, have a considerably lower output of greenhouse gasses than fossil fuels, and provide a flexible, low-cost supply of energy.[37] However, these technologies are far from perfect.

With wind power, several externalities must be considered. Power systems may face issues in operation because of the variability of wind electricity: the energy supply depends on weather conditions, and due to variable weather patterns, availability cannot be scheduled as needed.[38] Additionally, a short-term impact to consider is wind turbines causing wildlife deaths, and although long-term issues of habitat loss and noise pollution remain inconclusive and require further study, they should not be discounted as negligible.[39]

Hydropower has similar disadvantages. For example, damming interrupts the flow of rivers, harms local ecosystems, and displaces both people and wildlife.[40] Dams are expensive to build and must operate for decades before becoming profitable, all the while requiring very costly standards for safety.[41] Risks inherent to building large dams include geological damage, as evidenced by the earthquakes and depression of the earth's surface caused by the Hoover Dam, and if a dam is breached, there can be serious flooding and death.[42]

Some promising alternative renewable energy sources include biomass gasification, molten carbonate fuel cells fed with wood gas, offshore wind farms, solar photovoltaics, and solar thermal power plants.[43] However, each of these sources has several considerable barriers to wider use, including high costs of implementation, lack of proven

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[35] *See* UNION OF CONCERNED SCIENTISTS, *supra* note 33.
[36] *See id.*
[37] *See* Askari Mohammad Bagher, Mirzaei Vahid, Mirhabibi Mohsen & Dehghani Parvin, *Hydroelectric Energy Advantages and Disadvantages*, 2 AM. J. OF ENERGY SCI. 17, 18 (2015).
[38] *See* Zerrahn, *supra* note 32, at 247.
[39] *See id.*
[40] *See* Bagher et al., *supra* note 37.
[41] *See id.*
[42] *See id.*
[43] *See generally* Charikleia Karakosta, Charalampos Pappas, Vangelis Marinakis & John Psarras, *Renewable energy and nuclear power towards sustainable development: Characteristics and prospects,* 22 RENEWABLE AND SUSTAINABLE ENERGY REV. 187 (2013) (https://doi.org/10.1016/j.rser.2013.01.035).

reliability, and low energy density.[44] Another drawback of these technologies, which rely on battery-storage of produced energy to maintain reliability, is the scale and cost of the batteries. In 2018, the Clean Air Task Force reported that the state of California would need a vast quantity of undesirable and impractical batteries to store the energy coming from renewable sources and stated that this approach would have massive cost implications.[45]

Ultimately, several studies have shown that the use of nuclear energy across the world has contributed to the reduction of carbon dioxide emissions, while renewable energy has yet to make a significant positive impact.[46]

B. Historical Roots of Nuclear Power

Since its emergence in the 1940s, nuclear power has been the subject of intense scrutiny and public debate due to the fear surrounding the risk of meltdown, the association with weapons, and the myths perpetuated throughout society.[47] This section will survey the development of this energy source, major U.S. legislation relating to it, and notable nuclear accidents that have created the current status quo.

The first nuclear reactors were constructed during the Manhattan Project to produce the uranium and plutonium used in the Fat Man and Little Boy bombs, which were used by the U.S. against Japan at the end of the Second World War.[48] In the aftermath of that global conflict, the U.S. strove to attain civilian nuclear energy, dreaming of a future where

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[44] *See id.* at 191.

[45] Undesirable, because of the land use implications; impractical, because building the level of renewable generation and storage necessary to reach the state's goals of relying on renewable energy sources would drive up costs exponentially, from $49 per megawatt-hour of generation at 50% to $1,612 at 100% (with the assumption that the needed lithium-ion batteries would cost roughly a third of their 2018 price). *See* James Temple, *The $2.5 trillion reason we can't rely on batteries to clean up the grid*, MIT TECH. REV. (July 27, 2018), https://www.technologyreview.com/2018/07/27/141282/the-25-trillion-reason-we-cant-rely-on-batteries-to-clean-up-the-grid/#:~:text=Climate%20change-,The%20%242.5%20trillion%20reason%20we%20can't%20rely%20on%20batteries,to%20play%20a%20major%20role [https://perma.cc/A5UG-MBDD].

[46] *See* Karakosta et al, *supra* note 43, at 188.

[47] Michael Shellenberger, *If Nuclear Power Is So Safe, Why Are We So Afraid Of It?,* FORBES (June 11, 2018, 12:48pm EDT), https://www.forbes.com/sites/michaelshellenberger/2018/06/11/if-nuclear-power-is-so-safe-why-are-we-so-afraid-of-it/?sh=a3789f363859 [https://perma.cc/9UHM-48GY]. For more discussion, *see generally 10 myths about nuclear energy,* ARGONNE NATIONAL LABORATORY (September 9, 2013), https://www.anl.gov/article/10-myths-about-nuclear-energy [https://perma.cc/UC45-8Y3X].

[48] *Nuclear Reactors*, ATOMIC HERITAGE FOUND (June 2, 2017), https://ahf.nuclearmuseum.org/ahf/history/nuclear-reactors/ [https://perma.cc/6ZUR-DRCG] [hereinafter AHF]; *Outline History of Nuclear Energy*, WORLD NUCLEAR ASS'N (Updated November 2020), https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx [https://perma.cc/TPZ8-XXW5].

electricity would be "too cheap to meter."[49] In 1950, the Atomic Energy Commission (AEC) contracted the Argonne National Laboratory to establish the National Reactor Testing Station in Idaho.[50]

In 1951, the first breeder reactor[51] became operational, and it generated a usable quantity of electricity sufficient to power four light bulbs.[52] A second breeder reactor, twenty times the size of the first one, was then constructed, and it became a prototype for commercial reactors.[53] The 1950s then saw further testing of reactors, the spread of the atomic bomb and the invention of the hydrogen bomb, and two significant military developments: the nuclear-powered submarine and the nuclear-powered aircraft carrier, both using pressure water reactors (PWRs).[54] PWRs have since become the most widely used reactor type in civil nuclear power.[55] By the 1960s, the light-water reactor[56] had risen to prominence as the nuclear technology of choice in the U.S., and that has continued to be the standard.[57]

Concerns over safety, waste, and cost stagnated development somewhat in the decades that followed.[58] However, innovation has continued. In the 1990s, the U.S. Nuclear Regulatory Commission (NRC) certified several types of third-generation reactors,[59] and multiple distinct reactor types have steadily emerged across the world.[60] Most recently, the European Fast Reactor (EFR, or Sodium-Cooled Fast Reactor (SFR)) has become a promising generation four reactor type through international efforts.[61] Domestically, the U.S. Department of

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[49] *See id.*
[50] *See id.*
[51] A breeder reactor is a kind of reactor which converts uranium into plutonium while operating, creating more fuel than it uses up. "Breeder reactor," ENCYCLOPEDIA BRITANNICA (Dec. 18, 2018), https://www.britannica.com/technology/breeder-reactor [https://perma.cc/N48T-XA7Q].
[52] *See* AHF, *supra* note 48.
[53] *See id.*
[54] James Chater, *A History of Nuclear Power,* FOCUS ON NUCLEAR POWER GENERATION 28, 29 (2005).
[55] *See id.*
[56] A term used to describe reactors using ordinary water as a moderated coolant. *Light water reactor*, U.S. NUCLEAR REGUL. COMM'N (last updated Feb. 15, 2023), https://www.nrc.gov/reading-rm/basic-ref/glossary/light-water-reactor.html [https://perma.cc/4EQV-F7ZY].
[57] *See* Chater, *supra* note 54, at 31.
[58] *See id.* at 35.
[59] The U.S. Department of Energy classifies reactors by "generation." "Generation I" reactors were developed in the 1950s-60s; "Generation II" range from the 1960s to the present, as the distinction from "II" to "III" is somewhat arbitrary. "Generation III" reactors are considered "advanced reactors" and are still being constructed in many cases. "Generation IV" designs are still in development and will not be operational before the 2020s. *See Advanced Nuclear Power Reactors,* WORLD NUCLEAR ASS'N (last updated April 2021), https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors.aspx [https://perma.cc/RW8Q-EUT7].
[60] *See* Chater, *supra* note 54, at 35.
[61] *See* Karakosta et al, *supra* note 43, at 193.

Energy has announced plans to build a Versatile Test Reactor, capable of performing irradiation testing at very high neutron energy fluxes, in the hopes of accelerating the development of nuclear fuels, materials, instrumentation, and sensors.[62]

Historically, the U.S. has relied upon three major pieces of legislation to shape its approach to nuclear power. The first statute was the Atomic Energy Act (AEA) of 1946, which established the AEC as a regulatory body charged with promoting "utilization of atomic energy for peaceful purposes to the maximum extent consistent with the common defense and security and with the health and safety of the public."[63] The AEA was amended in 1954, with the current provisions including requirements that any civilian uses of nuclear materials and facilities be licensed.[64] The AEA also enumerates the powers of the AEC to establish and enforce standards to govern those civilian uses as "the Commission may deem necessary or desirable in order to protect health and safety and minimize danger to life or property."[65]

The AEA was again amended by the Price-Anderson Nuclear Industries Indemnity Act (PAA) in 1957 to establish compensation for, and impose limits on, licensee liability for injury to off-site persons or damage to property caused by nuclear accidents.[66] Under the PAA, the owners of commercial reactors must assume all liability for damages awarded to the public by the courts in the event of a nuclear accident, and they must waive most legal defenses in the event of an "extraordinary nuclear occurrence."[67] However, they are indemnified by the government against damage awards exceeding the maximum insurance commercially available to the nuclear power industry.[68] Within this act, there are specifications for causes of action in the case of a nuclear accident: a plaintiff's cause of action must be recognized by the

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[62] *Versatile Test Reactor*, OFF. OF NUCLEAR ENERGY, https://www.energy.gov/ne/versatile-test-reactor [https://perma.cc/C3R4-PDYH] (last visited November 9, 2022).
[63] *Summary of the Atomic Energy Act*, US ENVIRON. PROT. AGENCY (last updated March 21, 2022), https://www.epa.gov/laws-regulations/summary-atomic-energy-act [https://perma.cc/7534-UU4W]; 42 U.S.C. §2011 et seq. (1946).
[64] *Governing Legislation,* U.S. NUCLEAR REGUL. COMM. (last updated September 10, 2021), https://www.nrc.gov/about-nrc/governing-laws.html [https://perma.cc/4H7G-4XQV] [hereinafter "USNRC"]; 42 U.S.C. §§ 2011-2021, 2022-2286i, 2296a-2297h-13.
[65] *Id.*
[66] *Price-Anderson Act: Nuclear Power Industry Liability Limits and Compensation to the Public After Radioactive Releases,* CONG. RSCH. SERV. (February 5, 2018), https://crsreports.congress.gov/product/pdf/IF/IF10821#:~:text=Congress%20responded%20in%201957%20by,readily%20available%20within%20those%20limits [https://perma.cc/58Q5-7QZD].
[67] *See id.*
[68] *See id.*

law of the state where the accident occurs, and the cause of action must be a claim for property damage or a personal-injury claim.[69] This act was renewed in 2005 for a twenty-year period as part of the Energy Policy Act.[70]

The last major legislative action was the Energy Reorganization Act of 1974, which established the NRC to replace the AEC, in part—essentially, the Energy Reorganization Act split the functions of the AEC by assigning responsibility for development and production of nuclear weapons, promotion of nuclear power, and other energy-related work to what is now the Department of Energy, while assigning the regulatory work to the new NRC.[71] These delegations formed the foundation of the current nuclear regulatory scheme.

Of course, as much as regulators, innovators, and citizens alike have hoped for peaceful, safe expansion of commercial nuclear technology, there have been three major accidents since the advent of nuclear power that have informed the U.S.'s approach to regulating this field.
In March 1979, a reactor at the Three Mile Island plant in Pennsylvania partially melted down due to a combination of equipment malfunctions, design-related problems, and worker errors.[72] Although its small radioactive releases had no detectable health effects on plant workers or the public, its aftermath caused the NRC to increase its regulatory oversight, bringing about notable changes involving emergency response planning; reactor operator training; human factors engineering; radiation protection measures; and other areas of nuclear power plant operation.[73] Public fear and distrust also increased in the aftermath.[74]

The next disaster—the meltdown at the Chernobyl plant—is perhaps the most famous. On April 26, 1986, an accident during a reactor systems test led to a meltdown and rupture of a reactor core, causing a fire that released massive amounts of radioactive material into the environment.[75] Despite the Soviet government's intense containment efforts, the contamination covered wide areas of Belarus, Russia, and

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[69] 42 U.S.C. § 2210 (using definitions from §§ 2014(q) and (hh)).
[70] *The Price-Anderson Act,* CTR. FOR NUCLEAR SCI. AND TECH. INFO. (November 2005), https://cdn.ans.org/policy/statements/docs/ps54-bi.pdf [https://perma.cc/6YSN-234Q].
[71] *See* USNRC, *supra* note 64.
[72] *Backgrounder on the Three Mile Island Accident*, USNRC (Updated June 21, 2018), https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html [https://perma.cc/K6B4-R4NC].
[73] *Id.*
[74] *See id.*
[75] *Backgrounder on Chernobyl Nuclear Power Plant Accident,* USNRC (last updated March 1, 2022), https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/chernobyl-bg.html#response [https://perma.cc/JPN7-BELV].

Ukraine.[76] In the aftermath, there was panic over the physical effects the disaster might bring upon the people living nearby and the environment.[77] With respect to the environment, thousands of air, water, milk, vegetation, soil, and food samples were collected, and only very low levels of radionuclides were attributed to release from the accident; furthermore, comprehensive investigations have concluded that the effects of this contamination were negligible.[78] As for human health, the radiation effects killed twenty-eight of the site's six hundred workers in the first four months after the event, and another 106 workers received high enough radiation doses to cause acute radiation sickness.[79] However, the majority of the residents in the affected regions received very small radiation doses compared to natural background levels, and available evidence does not indicate a strong increase in radiation-induced leukemia or solid cancer among that population.[80] Although the physiological and environmental results have been far less severe than initially predicted,[81] there have nonetheless been serious psycho-social impacts on local residents and evacuees, including higher rates of depression, alcoholism, anxiety over potential health effects, and self-reported expectations of a short life.[82]

Chernobyl is infamous, and its name is practically synonymous with the dangers of nuclear power.[83] However, when the NRC assessed the situation, it determined that many factors protected U.S. reactors from the fate of the Chernobyl plant, and the agency publicly concluded that the lessons learned from Chernobyl fell short of requiring immediate changes in the NRC's regulations.[84]

The third prominent disaster occurred more recently. In 2011, a 9.0 magnitude earthquake damaged a reactor site in Fukushima, Japan,

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[76] *Id.*
[77] *See id.*
[78] *See id.*
[79] *See id.*
[80] *See id.* Although there was a statistically significant increase in thyroid cancer in the implicated populations, that is most likely because many children and adolescents drank milk contaminated with radioactive iodine, which delivered substantial doses to their thyroid glands.
[81] *See id.* The available evidence does not show any effect on the number of adverse pregnancy outcomes, delivery complications, stillbirths, or overall health of children among the families living in the most contaminated areas, and cancer deaths in general have been far lower than expected.
[82] *See id*.
[83] Judy Berman, *HBO's* Chernobyl *Isn't Just a Historical Drama—It's a Warning*, TIME (May 2, 2019), https://time.com/5581704/chernobyl-hbo-review/ [https://perma.cc/NPZ6-4QKH].
[84] *See* USNRC, *supra* note 75.

causing three reactor cores to overheat and melt.[85] This generated extreme pressure, which led to leaks of radioactive gas and hydrogen and an explosion that released more radioactive material.[86] The contamination spread over a large area of the country, requiring mass evacuation and relocation.[87] In the wake of this event, the NRC created a task force to review current U.S. regulations, and as a result, the agency issued three orders in 2012 requiring plants to maintain additional emergency equipment to support reactors following a natural disaster, install enhanced monitoring equipment, and improve or install emergency venting systems for reactors with designs similar to the Fukushima plant.[88] However, despite its conclusion that U.S. reactors could continue operating safely, the NRC tightened regulatory controls on power plants.[89]

C. Global Perspectives

In the U.S., despite receiving less subsidy assistance from the government than other energy industries[90] and facing significant regulatory constraints,[91] nuclear power plants supplied 19% of the total electrical output in the country in 2019.[92] As of August 1, 2023, this generation comes from ninety-three commercial nuclear reactors operating at fifty-four locations.[93] More may be added soon, as there have been sixteen license applications to build twenty-four new reactors since 2007.[94]

Outside of the U.S., nuclear power has become important in the energy sectors of various countries. In 2007, Sweden produced more

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[85] *Backgrounder on NRC Response to Lessons Learned from Fukushima,* USNRC (last updated October 18, 2022), https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/japan-events.html [https://perma.cc/4LYL-2TT5].
[86] *See id.*
[87] *See id.*
[88] *See id.*
[89] *See id.*
[90] Jocelyn Timperley, *The Fight to End Fossil Fuel Subsidies*, 598 SPRINGER NATURE LIMITED 403, 404 (Oct. 21, 2021). To make nuclear power competitive, in my proposal or any other, it will be important to end the subsidies going to fossil fuels, regardless of whether a larger one is apportioned for nuclear energy.
[91] Joshua Antonini, *Nuclear Wasted: Why the Cost of Nuclear Energy is Misunderstood*, MACKINAC CTR. (July 25, 2022), https://www.mackinac.org/blog/2022/nuclear-wasted-why-the-cost-of-nuclear-energy-is-misunderstood [https://perma.cc/9BHH-MSV3].
[92] *Nuclear Power in the USA,* WORLD NUCLEAR ASS'N (last updated Nov. 2022), https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.aspx [https://perma.cc/M9SG-936M].
[93] *Nuclear explained*, U.S. ENERGY INFORMATION ADMINISTRATION (last updated August 24, 2023), https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php [https://perma.cc/5E2V-NXWE].
[94] *See* WORLD NUCLEAR ASS'N, *supra* note 92.

electricity per capita by nuclear reactors than in any other country in the world.[95] However, costs have always been a major concern, and the government has vacillated dramatically in its policies—at certain points committing to close all reactors, and at others, re-regulating to introduce competition between producers and revoking the decommissioning vow.[96] In recent years, legislative changes are being made to enable new nuclear power growth, including shortening licensing processes and creating administrative fast-tracks to allow for the building of both conventional large-scale reactors and small modular reactors (SMRs).[97] As for public opinion, a poll taken at the end of December 2022 showed that 59% of Swedes said they are ready to continue embracing nuclear power and, if necessary, to build more reactors; only 8% of respondents wished for the plants to be shut down.[98]

China has a long history of developing nuclear power, and according to Chinese scholars, the current state of its energy and environmental resources make nuclear power the "inevitable" choice for sustainable development.[99] In light of Fukushima, the government has emphasized safety and imposed regulations, but the industry has innovated, and technologies out of China have been adopted in Pakistan, Britain, and Argentina.[100] In China, problems with cost and organization remain, but nuclear power has rapidly developed, and its future seems promising.[101] With twenty-seven reactors operational as of 2016, China has twenty-four units under construction, comprising 36% of the world's total construction capacity.[102] Although the country also plans to develop its hydro, wind, and solar energies, the dominant view is that nuclear power has an irreplaceable role in ensuring energy security, reducing carbon dioxide emissions, and achieving sustainable, low-carbon development.[103]

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[95] Tomas Kåberger, *History of nuclear power in Sweden,* 21 ESTUDOS AVANÇADOS 225, 226 (2007), (https://www.scielo.br/j/ea/a/WvX97FxmVshDWXjYMhG8Jgh/?format=pdf&lang=en).
[96] *See id.* at 229-30.
[97] Charles Szumski & Pekka Vanttinen, *Swedish government frees up legislation on nuclear expansion*, EURACTIV (January 11, 2023), https://www.euractiv.com/section/politics/news/swedish-government-frees-up-legislation-on-nuclear-expansion/ [https://perma.cc/4P32-WFFH].
[98] *Id.*
[99] Ming Zeng et al, *Review of nuclear power development in China: Environment analysis, historical stages, development status, problems and countermeasures*, 59 RENEWABLE AND SUSTAINABLE ENERGY REVIEWS 1369, 1376 (2016) (https://doi.org/10.1016/j.rser.2016.01.045).
[100] *See id.* at 1376-77.
[101] *See id.* at 1378-79.
[102] Qi-Zhen Ye, *Safety and effective developing nuclear power to realize green and low-carbon development*, 7 ADVANCES IN CLIMATE CHANGE RESEARCH 10, 11 (2016) (https://www.sciencedirect.com/science/article/pii/S1674927816300168?via%3Dihub).
[103] *See id.* at 11-12.

A final example is Japan post-Fukushima. The public attitude used to be fairly neutral or accepting of nuclear power, but that perception shifted in the wake of the disaster; in 2012, 57% of citizens reported their opposition to reopening reactors that the government had closed for maintenance, and in 2011, 68% of respondents expressed a desire for Japan to reduce its use of nuclear energy.[104] Even so, there are indications from the government that it will not adhere to the people's desires to reduce nuclear power development. Since the first two reactors restarted in 2015, eight more have restarted, and as of October 2022, another fifteen operable reactors are in the approval process, with two under-construction reactors also applying for approval.[105] In light of the war between Ukraine and Russia, Japan's prime minister announced an acceleration of the restarting of nine reactor units by winter 2022, with an additional seven units being restarted by summer 2023.[106] In December 2022, Japan announced a new policy to maximize the use of existing reactors by restarting as many as possible; prolonging the operating life of aging units beyond a sixty-year limit; and also developing next-generation reactors.[107] The plan was endorsed by the Nuclear Regulation Authority, Japan's nuclear watchdog.[108] However, it may take some time before progress can be made with the reboot of the nuclear industry, as the labor pool and manufacturing capacity have atrophied in the years since Fukushima.[109]

Countries around the world continue to rely on and promote nuclear power, despite concerns over safety and confusion over the governmental approaches. If the U.S. it is to remain competitive on the global stage and match calls for sustainable development, it must equally advance its nuclear power industry. The U.S. population has adopted a relatively

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[104] Takaaki Kato et al., *A case study of economic incentives and local citizens' attitudes toward hosting a nuclear power plant in Japan: Impacts of the Fukushima accident,* 59 ENERGY POLICY 808 (2013) (https://doi.org/10.1016/j.enpol.2013.04.043). https://www.sciencedirect.com/science/article/pii/S0301421513002966. This article is useful reading on the topic of host community perceptions of power plants, and how economic considerations can offset harms and perceived harms.

[105] *Nuclear Power in Japan*, WORLD NUCLEAR ASS'N (last updated October 2022), https://world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx [https://perma.cc/YJ37-M7NH].

[106] *See id.*

[107] Mari Yamaguchi, *After the Fukushima disaster, Japan swore to phase out nuclear power. But not anymore,* THE ASSOCIATED PRESS (December 22, 2022), https://apnews.com/article/russia-ukraine-business-japan-climate-and-environment-02d0b9dfecc8cdc197d217b3029c5898 [https://perma.cc/3BCF-GHLV].

[108] *Id.*

[109] Eri Sugiura & Kana Inagaki, *Japan's nuclear restart hit by engineer and manufacturing capacity shortages*, FINANCIAL TIMES (January 3, 2023), https://www.ft.com/content/e179ece0-6e0b-4ce7-98b5-30ae01d41501 [https://perma.cc/KU8G-XTNZ].

favorable view of nuclear power in recent years. A 2021 survey found that 76% of respondents said they strongly or somewhat favored the use of nuclear energy as one of the ways to provide electricity, whereas only 24% were in opposition, and most Americans—83%—believe that nuclear energy will be important in meeting the nation's electricity needs in the future.[110] This approval should be a motivating factor for the government to pursue nuclear energy.

III. THE REGULATORY REACTION

A. Judicial Influence

Since the creation of the AEC, judicial scrutiny of nuclear questions has been limited, and attempts to question the nuclear legislation have been blocked by the Supreme Court's extreme deference to agency expertise, leading to what one scholar has called "the legal system's abdication to the technocracy."[111] Apart from a few judges in the early days of the nuclear industry's development, the courts have come alongside Congress to give the NRC "almost carte blanche powers" to control nuclear power in the U.S.[112]

In the 1960s, the original congressional provision for a nuclear energy option was interpreted by the courts as a mandate for nuclear power, which meant that attempts to control radioactive materials—efforts that would potentially halt the growth of nuclear power—were cut off by the judiciary.[113] This led to foreclosure of state and local actions regarding nuclear power matters by federal preemption.[114] The Supreme Court deferred to the scientists of the AEC, making a policy decision to reply on the assurances given by those scientists that public safety would not be compromised.[115] This reliance defined the Court's approach to nuclear power issues in the following decades, defeating many attempts to control the actions of the AEC and NRC.[116]

The 1970s ushered in a period of heightened concern, marked by emerging questions about waste disposal and financial accountability for

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[110] Ann S. Bisconti, *May 2021 National Public Opinion Survey: Support for Nuclear Energy Groups with Climate Change Concerns*, BISCONTI RESEARCH, INC., https://www.bisconti.com/blog/climate-change-concerns [https://perma.cc/U4P5-9DDP].
[111] Diane Carter Maleson, *The Historical Roots of the Legal System's Response to Nuclear Power*, 55 S. CAL. L. REV. 597, 607 (1982).
[112] *See id.*
[113] *See id.* at 610.
[114] *See id.* The two major cases from this era will be discussed in the next section of this paper.
[115] *See id.* at 613.
[116] *See id.*

nuclear accidents.[117] The case *Northern Indiana Public Service Co. v. Porter County Chapter of the Izaak Walton League of America, Inc*. involved a challenge to the AEC's interpretation of its own regulations,[118] and the Supreme Court had to consider the nuclear waste disposal problem for the first time in *Vermont Yankee Nuclear Power Corp. v. Natural Resources Defense Council, Inc.*[119] Near the end of the decade, in *Natural Resources Defense Council, Inc. v. NRC,* the Court reviewed the legislative history of the Administrative Procedure Act[120] and emphasized that Congress had intended that the discretion of the agencies, rather than the court, should be exercised in determining when extra procedural devices should be employed.[121] In the majority opinion, Justice Rehnquist stated:

> Nuclear energy may some day be a cheap, safe, source of power or it may not. But Congress has made a decision to at least try nuclear energy, establishing a reasonable review process in which courts are to play only a limited role. The fundamental policy questions appropriately resolved in Congress and in the state legislatures are *not* subject to reexamination in federal courts under the guise of judicial review of agency action.[122]

This case established the Court's approach to nuclear power: unless constitutional issues or exceptionally compelling circumstances are at stake, agencies should be free to devise their own protocols for managing nuclear power plants.[123]

In 1972, the Supreme Court accepted review of *Northern States Power Co. v. State of Minnesota* and affirmed the judgment of the 8th Circuit. In 1969, the Northern States Power Company ("Northern") brought suit against the State of Minnesota to decide the issue of whether the federal government, through the AEC, had exclusive authority to

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[117] *See id.* at 620-627.
[118] *See id.* at 618.
[119] *See id.* at 621.
[120] The APA prescribed fair administrative procedures, providing a means through which administrative procedures could be conducted in an orderly fashion, and by which administrative law and procedure might more effectively serve the public. *See* 92 CONG. REC. 2149 (1946).
[121] *See* Maleson, *supra* note 111, at 623.
[122] *See* Vermont Yankee Nuclear Power Corp. v. Nat. Res. Def. Council, Inc., 435 U.S. 519, 557–58 (1978).
[123] *See* Maleson, *supra* note 111, at 623.

regulate the radioactive waste releases from nuclear power plants, thereby precluding the state from regulating such discharges from the company's Monticello plant.[124] Minnesota asserted that regulation of radioactive waste was within the State's Tenth Amendment authority to protect and promote the health, safety, and general welfare of its citizens, and it maintained that the AEA neither expressly nor impliedly preempted state authority to regulate radioactive waste issuing from nuclear power plants.[125] In contrast, Northern argued that there was clear evidence of the congressional intent that the AEC should have exclusive control over these regulations, and it contended that nuclear energy was an area demanding national controls.[126] At the district and appellate levels, the courts ruled in favor of Northern, and the Supreme Court concurred by merely stating, "Judgment affirmed."[127] This decision was likely influenced by the fact that only a small group of companies were manufacturing nuclear power at that time, and if they had been forced to comply with different regulatory standards in each state, the cost of compliance would have been unsustainable.[128] Since promotion of nuclear power was interpreted as key to Congressional design, implied preemption by the AEC was the only choice for the courts.[129] This early case set the tone for subsequent cases where courts prioritized options that would enable the advancement of nuclear power plants, weighing the legislature's promotional goal more than the safety goal.[130]

In 1978, the Court accepted review of *Duke Power Co. v. Carolina Environmental Study Group*, a case concerning the PAA. Duke Power Co., while constructing nuclear power plants in North and South Carolina, was sued by the Carolina Environmental Study Group, which sought to have the PAA declared unconstitutional.[131] The District Court held that the act violated the Due Process Clause of the Fifth Amendment for several reasons: 1) the prescribed amount of recovery was not rationally related to potential losses; 2) the act tended to encourage irresponsibility in matters of safety and environmental protection; 3) there was no *quid pro quo* for the liability limitation; and 4) the act offended equal protection by forcing the victims of a nuclear incident to

[124] N. States Power Co. v. State of Minn., 447 F.2d 1143, 1144 (8th Cir. 1971), *aff'd sub nom.* Minnesota v. N. States Power Co., 405 U.S. 1035 (1972).
[125] *See id.* at 1145.
[126] *See id.*
[127] *See* 405 U.S. 1035 at 1037.
[128] *See* Maleson, *supra* note 111, at 615.
[129] *See id*.
[130] *See id.*
[131] *See* Duke Power Co. v. Carolina Env't Study Grp., Inc., 438 U.S. 59 (1978).

bear the burden of injury, even though society as a whole benefits from the existence and development of nuclear power.[132]

The Supreme Court reversed this decision, holding that the PAA did not violate the Fifth Amendment.[133] The Court determined that 1) the statutory limit on liability encouraged private industry participation and therefore bore a rational relationship to Congress's concern for stimulating private industry involvement in the production of nuclear energy; 2) the Congressional decision to fix a ceiling of recovery was within permissible limits given the extremely remote possibility of an accident exceeding that level of liability; and 3) the act did not encourage irresponsibility because nothing in the liability-limitation provision undermined or altered the rigor and integrity of the process involved in licensing a nuclear power plant and, in the event of an accident, the utility itself would probably suffer the largest damage.[134] The Court stated that the PAA provides a reasonable substitute for common law or state tort law remedies, and it held there was no Equal Protection violation because the logic of the limitation on liablity was ample justification for the difference in treatment between those injured in nuclear accidents and those injured otherwise.[135] Through its decision, the Court treated the District Court's concerns for safety as obstructionist, thereby indicating that it would take a serious nuclear accident to dislodge the judicial mindset of deference to the promotion of nuclear power.[136]

The Supreme Court decided the case *Pacific Gas and Electric Co. v. State Energy Resources Conversation & Development Commission* in 1983. The Court held that the AEC was given exclusive jurisdiction to license the transfer, delivery, receipt, acquisition, possession, and use of nuclear materials, leaving no role for the states.[137] However, the Commission was not given authority over the generation of electricity itself from nuclear plants, nor over the economic question whether a particular plant should be built.[138] The Court held that the statute was outside the federally occupied field of nuclear safety regulation because the California Assembly Committee on Resources, Land Use, and Energy reported that the waste disposal problem addressed by the

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[132] *See id.* at 59-60.
[133] *See id.* at 60-61.
[134] *See id.*
[135] *See id.* at 61.
[136] *See* Maleson, *supra* note 111, at 627.
[137] *See* Pac. Gas & Elec. Co. v. State Energy Res. Conservation & Dev. Comm'n, 461 U.S. 190, 207 (1983).
[138] *See id.*

statute[139] was "largely economic or the result of poor planning, *not* safety related."[140] While not entirely at odds with the decision in *Northern States Power Co.*, this decision could be seen as a shift toward greater consideration for safety concerns and the adoption of a more permissive stance on regulation in the judicial mindset

The most prominent recent case regarding nuclear power is *June v. Union Carbide Corp.* This suit arose in 2009 out of alleged radiation injuries to residents of Uravan, Colorado—a former uranium and vanadium milling town owned and operated by Union Carbide and Umetco Minerals Corporation.[141] The plaintiffs brought an action under the PAA, asserting claims for personal injury based on disease or death caused by radiation, as well as claims for medical monitoring to detect the onset of disease in the plaintiffs who were asymptomatic.[142] The Tenth Circuit held that the plaintiffs' personal-injury claims failed for lack of evidence of factual causation,[143] and their medical-monitoring claims failed for lack of evidence of a "bodily injury" as required by the PAA.[144] This case was not elevated to the Supreme Court, but the focus on the need for clear "but-for" causation, coupled with the court's reluctance to acknowledge allegations of nuclear injuries, indicates that the judiciary has yet to turn from preferring enablement of nuclear power development.

B. Policy Stagnation

As previously mentioned, the NRC replaced the AEC by statute in 1974, and Congress charged it with the duty of protecting people and the environment from "unnecessary exposure" to radiation as a result of civilian uses of nuclear materials.[145] Today, it almost functions like a legislature.[146] However, the problems it has perpetuated and engendered began with its predecessor agency. The AEC released "Regulatory

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[139] The statute imposed a moratorium on the certification of new nuclear plants until the Energy Commission found that there had been developed, and that the U.S. through its authorized agency had approved, and there existed a demonstrated technology or means for the disposal of high-level nuclear waste. *See id.* at 198.
[140] *See id.* at 213, 216.
[141] June v. Union Carbide Corp., 577 F.3d 1234, 1237 (10th Cir. 2009).
[142] *See id.*
[143] *See id.* at 1247.
[144] *See id.* at 1248.
[145] *See Radiation Protection*, USNRC (last updated September 10, 2021), https://www.nrc.gov/about-nrc/radiation.html [https://perma.cc/H4H9-D2NA].
[146] The Commission members meet regularly, reviewing reports, and issues are decided by majority vote. *See Commission Direction-Setting and Policymaking Activities*, USNRC (last updated September 10, 2021), https://www.nrc.gov/about-nrc/policymaking.html [https://perma.cc/BXB6-K6FJ].

Guides"—which became *de facto* regulation under the NRC—and by January 1, 1971, the U.S. had hundreds of codes and standards for nuclear plant construction and design.[147] By 1975, that number surpassed 1,600, and by 1978, an average of 1.3 new regulatory or statutory requirements were being imposed on the nuclear industry every working day.[148] As a result, unit costs began to escalate.[149] Nonetheless, this was not the NRC's highest priority. Before the Three Mile Island incident, regulations placed the burden of proof on the regulators to justify negative findings on safety matters, and only the most conservative requirements consistent with the commercial viability of nuclear power were mandated.[150] However, post-Three Mile Island, the NRC's complacency was shattered with regards to reactor hazards, and the nuclear industry was put on notice by then-Chairman Hendrie of the NRC that "safety [not costs] must be the dominant element in [the NRC's] considerations."[151]

Nothing indicates that this attitude has changed today. Tellingly, two burdensome approaches from the 1970s remain in place: the "as low as reasonably achievable" (ALARA) policy and the Linear No Threshold (LNT) model.[152] ALARA refers to the AEC policy that required all nuclear power plants to reduce radioactive emissions to an amount *as low as reasonably achievable*.[153] The LNT is a dose-response model used to estimate the negative health consequences of exposure to ionizing radiation which extrapolates the damages from high-doses of radiation, known to empirically result in harm, in a linear model down to extremely low-doses of radiation.[154] The LNT assumes that exposure to any level of ionizing radiation leads to a marginal increase in the probability that a human will suffer from radiation-induced cancer or other health issues.[155] Although the NRC and the EPA endorse the LNT, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has not used the LNT when analyzing the harms caused by low-dose exposures to ionizing radiation for decades.[156] In light of research

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[147] *See* VACLAV SMIL, ENERGY MYTHS AND REALITIES 36 (American Enterprise Institute Press eds. 2010).
[148] *See id.*
[149] *See id.*
[150] This was stated by NRC Commissioner Gilinsky in 1979; *see* CHARLES KOMANOFF, POWER PLANT COST ESCALATION 34 (1981), (https://www.komanoff.net/nuclear_power/Power_Plant_Cost_Escalation.pdf).
[151] *See id.* (citing J.M. Hendrie's Speech at the AIF International Conference on Financing Nuclear Power in Copenhagen, 24 September 1979).
[152] *See* Dever, *supra* note 15.
[153] *See id.*
[154] *See id.*
[155] *See id.*
[156] *See id.*

conducted on the question of radiation exposure, the LNT is outdated and inaccurate for assessing risk.[157] Its continued application by the NRC has significant policy implications and stands to hinder nuclear power development, as the LNT in combination with ALARA imposes an undue burden on the industry.[158]

Setting those policies aside, regulation in general stands to limit the potential for innovation. As Richard B. Stewart posited in a California Law Review article:

> Regulation may adversely affect market innovation in four ways: (1) by imposing technical constraints on firms; (2) by forcing firms to make additional expenditures or outlays; (3) by causing uncertainty; and (4) by causing delay. The extent of these effects is a function of the stringency of the regulation and the regulatory tools employed.[159]

Furthermore, Stewart claimed that, with limited exceptions, Congress and administrative agencies have not been concerned with market innovation[160] in designing and implementing regulatory programs for various industries.[161] Stewart asserts that Congress and administrative agencies focus instead on enforcement, uniformity, and avoidance of disruption, which often hinders incentives for market innovation.[162]

If Congress and the NRC are primarily concerned with safety, and there are fears that current reactor technologies are unsafe, then the solution is clear: the nuclear power industry must innovate to improve reactor technologies and power plant designs. This solution is not something that will be accomplished through further regulations, but it may be accomplished through enabling this industry and the market to operate freely.

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[157] For discussion of relevant research, *see generally* Jerry M. Cuttler, *Commentary on Using LNT for Radiation Protection and Risk Assessment*, *in* DOSE-RESPONSE (INT'L DOSE-RESPONSE SOCIETY 2010), *doi:10.2203/dose-response.10-003.Cuttler.*

[158] *See* Dever, *supra* note 15; *see also* Cuttler, *supra*, at 379: "Although the LNT assumption is still widely accepted, it does not reflect reality, and its continued use is causing great social harm, particularly by constraining wider use of nuclear energy and CT diagnostic scans."

[159] *See* Stewart, *supra* note 16, at 1279.

[160] Stewart defines market innovation as product or process innovations that create benefits that firms can capture through the sale of goods and services in the market. *See id.* at 1279.

[161] *See id.* at 1288.

[162] *See id.*

Nuclear power will surely be a part of the future for the U.S. energy sector, but reforms to the current status quo are needed for this future to be successful. A 2009 MIT review of nuclear power concluded, "[t]he sober warning is that if more is not done, nuclear power will diminish as a practical and timely option for deployment at a scale that would constitute a material contribution to climate change risk mitigation."[163] That sentiment holds even more relevance today than it did at the time it was expressed, and the primary driver of a sustainable future through nuclear power must be a fundamental element of how the U.S. approaches regulating its nuclear power plants.

IV. ENRICHING THE FUTURE

In their 1997 paper *The Economics of Nuclear Accident Law*, Canadian scholars Michael Trebilcock and Ralph A. Winter outlined a proposal for an optimal nuclear power plant liability scheme in countries like the U.S. and Canada: "full strict liability for the [power plant] operator; joint and several liability with upstream suppliers, with the upstream suppliers' liability being restricted to a negligence standard; mandatory liability insurance to be provided by the market to some extent, and above this amount by the government."[164] They further proposed allowing the "hold harmless" clauses[165] prevalent in existing contracts between suppliers and operators, but argued that the liability extending beyond what would be covered by the operator's assets and insurance in the event of an accident should revert back to the supplier in cases of supplier negligence.[166] Their concept of a liability insurance market represents an *ex ante*[167] market mechanism for establishing safety incentives that would operate in parallel with government regulation.[168]

While this model has many merits, it has its shortcomings. Government forces are often incompatible with the will of the market, as

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[163] John M. Deutch et al., *Update of the MIT 2003 Future of Nuclear Power*, MASS. INST. OF TECH. (2009).
[164] Michael Trebilcock & Ralph A. Winter, *The economics of nuclear accident law*, 17 INT'L REV. OF LAW AND ECONOMICS 215, 216 (1997) (https://doi.org/10.1016/S0144-8188(97)00004-5).
[165] Clauses providing for the transfer of liability from suppliers to the operator; Trebilcock and Winter argue that these clauses can be justified through the best-placed decider principle of optimal tort liability. *See id.* at 217.
[166] *See id.* at 217.
[167] Meaning "before the event," corresponding to the legal term *a priori*. *Ex ante* regulations are predictive in nature and seek to prevent speculative harms from arising in the future. This is in contrast to *ex post* regulations (such as tort liability) that regulate externatlities after the harm has occurred. *See* Charles D. Kolstad et al., *Ex Post Liability for Harm vs. Ex Ante Safety Regulation: Substitutes or Complements?*, 80 THE AMERICAN ECONOMIC REVIEW 888 (1990) (http://www.jstor.org/stable/2006714).
[168] *See id.* at 217.

regulations can deter entrepreneurship and discourage market entry.[169] Increasing competition has a positive effect on innovation,[170] and although *ex ante* regulations are intended to prevent market failures, out-of-date *ex ante* regulations could themselves be the cause of market failures because they are poorly suited to sectors that evolve rapidly, resulting in a stifling of innovation.[171] Therefore, despite agreeing with much of what they argue, I disagree with the proposal of Trebilcock and Winter. The only path forward for the nuclear power industry involves freeing market forces from government influence.

It is true that the other countries surveyed above have not pursued deregulation as a means of advancing their nuclear power structures, apart from the slight changes made in Sweden. However, deregulation and consolidation of U.S. nuclear reactors are associated with a 10% increase in operating efficiency, achieved primarily by reducing the frequency and duration of reactor outages.[172] These results imply a substantial increase in electricity production.[173] Therefore, I argue that any country that wants to keep up with the energy demands of the future and wholeheartedly pursue renewable energy solutions must adopt the deregulation approach outlined below.

A. My Proposal: Economics and the Law

For many goals, including the reduction of pollution or the control of toxic waste, economic incentives are the best means of achieving compliance.[174] Economic incentive systems can use market principles to achieve environmental goals while avoiding many of the dysfunctions of regulations.[175] Under these systems, decentralized flexibility affords many advantages over regulation, such as cost savings, reduced delays

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[169] James Bailey & Diana Thomas, *Regulating Away Competition: The Effect of Regulation on Entrepreneurship and Employment*, MERCATUS CENTER (September 9, 2015), https://www.mercatus.org/publications/regulation/regulating-away-competition-effect-regulation-entrepreneurship-and [https://perma.cc/JE5R-KKN7].

[170] Xavier Vives, *Innovation and Competitive Pressure,* 56 THE JOURNAL OF INDUSTRIAL ECONOMICS, 419, 420 (2008) (https://doi.org/10.1111/j.1467-6451.2008.00356.x).

[171] Badri Narayanan & Hosuk Lee-Makiyama, *Economic Costs of Ex ante Regulations*, ECIPE OCCASIONAL PAPER 3 (October 2020), https://ecipe.org/publications/ex-ante/ [https://perma.cc/BZ2Q-3CEK].

[172] Lucas W. Davis & Catherine Wolfram, *Deregulation, Consolidation, and Efficiency: Evidence from U.S. Nuclear Power* 2, NAT'L BUREAU OF ECONOMIC RSCH. (August 2011) (http://www.nber.org/papers/w17341).

[173] *Id.*

[174] For a thorough discussion of this notion, as well as for elaboration on the points that follow in this article, *see generally* Richard B. Stewart, *Controlling Environmental Risks through Economic Incentives*, 13 COLUM. J. ENVTL. L. 153 (1988).

[175] *See id.* at 158.

and penalties, and the preservation of a desire to innovate.[176] The U.S. relies heavily on the market and private ordering for social and economic institutions, and thus, economic incentives are likely to do far better than regulatory laws when it comes to managing risk.[177] Economic incentives do not penalize new investment and harm competitiveness, and they give industries continuing incentives to develop environmentally superior processes to maintain reduced risk levels.[178]

Research into nuclear technologies is constantly ongoing and is generating many promising developments. As discussed earlier, there is a global effort to develop fourth-generation reactors, and advanced SMRs and accident-tolerant fuels are of key importance.[179] Safety concerns are a primary driver of these innovations, and the progress made in these technologies is a promising sign that even the most difficult pieces of the nuclear puzzle, such as waste disposal, will be successfully addressed in the future. The nuclear power industry has shown time and again, across various conditions, that it is willing to work for a future for this energy source. Therefore, the first step towards freeing the nuclear power industry from the choking grip of regulation is to exercise trust in the rationality[180] of the companies that exist and will emerge to fill this developing sector. The companies will have their own vested interests in safety and efficiency without regulatory authorities hovering over them.[181]

The second step is to define the incentives that are best suited to control the nuclear power industry. I submit that those incentives are the presence of insurance linked to a market for catastrophe bonds and options for consumer-company negotiation.

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[176] *See id.* at 159-160.
[177] *See id.* at 162.
[178] *See id.* at 163.
[179] *3 Innovations Transforming the Nuclear Industry*, OFFICE OF NUCLEAR ENERGY (June 5, 2018), https://www.energy.gov/ne/articles/3-innovations-transforming-nuclear-industry [https://perma.cc/BX3H-LJZ3].
[180] Used herein, rationality refers to the economic concept that people and entities make decisions to maximize utility—that is, the benefit to them. In this case, the benefit is, of course, monetary; nuclear power companies will make decisions that will be most profitable to them, and because of industry pressures, those decisions will necessarily be environmentally friendly.
[181] Interestingly, there is already some data that may indicate that safety is improved by deregulation; divestiture and consolidation have been associated with a non-negligible decrease in the number of emergency shutdowns of power plants. Richer data and analysis are needed to confirm this, but these results are suggestive. *See* Davis & Wolfram, *supra* note 172, at 3.

To begin, it is necessary to address the shortcomings of the current insurance scheme that controls the nuclear power industry, one which flows from the previously described PAA. Under the PAA today, owners of nuclear power plants pay an annual premium for $450 million in private insurance for offsite liability coverage per reactor site.[182] That primary tier of insurance is supplemented by a second tier, which is defined by the assessment of a prorated share of the excess damages above $450 million—up to $131.056 million per reactor.[183] This secondary tier therefore accounts for about $12.9 billion in coverage.[184] Finally, the third tier is relevant if the court determines that public liability may exceed the maximum amount of protection afforded by the first and second tiers. In such an event, each licensee will be assessed a pro rata share of the excess, not to exceed 5% of the maximum deferred premium.[185] This results in an allowance of approximately $6.553 million per reactor.[186]

Therefore, the PAA imposes a limit on liability for nuclear power plant operators, but that limit is a socially and economically inefficient mechanism. In an article on the role of government insurance in catastrophes, J. David Cummins argues that government involvement in the market for natural catastrophe insurance (distinguished from acts of terrorism) should be minimized to avoid crowding out the more efficient private market solutions.[187] Cummins proposed catastrophe bonds as one such market solution and suggested that while federal "make available" requirements may have a role, the private market alternatives to federal insurance ought to take center stage.[188] That is the position assumed for the purposes of this article. The current scheme under the PAA is not only inadequate, but fundamentally a fatally flawed approach. Market forces, such as those outlined herein, will always be able to construct a better liability scheme than that which currently exists.

Trebilcock and Winter make a strong argument for full strict liability to producers, positing that strict liability is the best way to elicit efficient care decisions and efficient activity level decisions because it

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[182] *Backgrounder on Nuclear Insurance and Disaster Relief*, USNRC (last updated April 11, 2022), https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/nuclear-insurance.html [https://perma.cc/8UP4-JNXN].
[183] *See id.*
[184] *See id.*
[185] *See id.*
[186] *See id.*
[187] J. David Cummins, *Should the Government Provide Insurance for Catastrophes?*, 88(4) FED. RESERVE BANK OF ST. LOUIS REV. 337 (2006).
[188] *See id.*

forces the producer to bear the full social costs and benefits of their decisions, while the activity level is determined by a true market price.[189] They assert that a limit on liability for producers under strict liability leads to inefficiencies in both care and activity, as the accident costs are not fully internalized.[190] This is attached to a principle in the economics of torts: the assignment of a higher share of accident costs to one tortfeasor will improve that individual's incentives to avoid an accident, even in a mixed tort-regulation incentive system.[191]

The limit on liability is one of the issues with the PAA, but the existence of a subsidy is another. It appears correct to consider the risk management system under the PAA as a subsidy since the liability has been shifted to the federal government and the victims due to its being capped.[192] In their article on nuclear liability subsidies, Faure and Fiore argue that the inefficiencies created by a government nuclear subsidy are of three kinds: the generation of an artificial competitiveness of nuclear energy, the lack of provision of sufficient incentives to the operators to prevent accidents, and the deficiency of the compensation capacity for victims in the case of an accident.[193] Considering this to be true for the PAA as well as international counterparts, Faure and Fiore conclude that because a substantial part of the damages resulting from a nuclear accident will remain uncompensated under the PAA and are, therefore, not adequately internalized by nuclear operators, this current regime of liability is suboptimal.[194]

Hence, in the context of insurance, my proposal is to be understood as an elimination of the PAA structure by Congress. Given the goal of incentivizing innovation in product efficiency and safety, it is imperative that all costs be internalized to producers such that benefits are maximally conveyed to both sides of the supply and demand. The full enjoyment of nuclear power for both civilians and the industry can only be realized through strict liability unlike that which is detrimentally cushioned by the PAA. Insurance companies, by nature, operate by assessing risk and thereby calculating premiums. Thus, they can provide

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[189] *See* Trebilcock & Winter, *supra* note 164, at 222.
[190] *See id.*
[191] *See* Trebilcock & Winter, *supra* note 164, at 227.
[192] Samuel B. Hardy, *Federal Subsidy of Adjudicative Right Determination: The New Cost Shifting of Nuclear Power Litigation*, 59 ALA. L. REV. 1705, 1712 (2008).
[193] Michael G. Faure & Karine Fiore, *An Economic Analysis of the Nuclear Liability Subsidy*, 26 PACE ENVTL. L. REV. 419, 437 (2009).
[194] *See id.* at 446.

the incentives for safe operation and construction by setting prices for their protections with no need for government intervention.

Catastrophic losses, such as those that would be incurred by a nuclear accident, would admittedly stress a conventional insurance system. At first glance, it may seem impossible to conceive that the industry could bear the entirety of a risk of this magnitude without subsidy or support from the federal government. Traditional insurance deals with a transfer of risk at a price fixed *ex ante*. This system presupposes that a premium corresponding to a taken risk can be calculated, requiring that 1) the insurer can calculate the expected loss of risk, and 2) following the law of large numbers, the risks insured must be numerous, making the total damage cost approach the underlying probability.[195] These requirements admittedly fail with respect to nuclear accidents. There can be some prediction of accident probabilities for nuclear power plants, but so many factors go into the possibility of risk that it may be impossible to devise a calculation that is sufficiently certain for insurance companies. There are also relatively few significant risks apart from a reactor meltdown and the leaking of radioactive materials into the surrounding environment.

However, linking the pooling ability of insurance companies to asset markets would create financial capacity sufficient to bear even the most pessimistic estimated losses.[196] In 2000, the capital and surplus of insurers and reinsurers of property and casualty in the U.S. was assessed at around $230 billion, with similar assessments suggesting that the U.S. capital market is 60 to 80 times larger.[197] Hedge funds, pension funds, and other diversified capital portfolios, which handle large volumes of capital much more than insurers, would be better able and perhaps more willing to absorb the risk of a nuclear accident.[198] In the current scheme, catastrophe bonds are a feature of the insurance-linked securities market. Catastrophe bonds are structured so that payment of interest or principal to the reporting insurance company depends on the occurrence of a

[195] M. Radetzki & M. Radetzki, *Private Arrangements to Cover Large-scale Liabilities Caused by Nuclear and Other Industrial Catastrophes*, 25 GENEVA PAP RISK INSUR. ISSUES PRACT 180, 182 (2000) (https://doi.org/10.1111/1468-0440.00058).

[196] *See* Olivier Mahul, *Managing Catastrophic Risk through Insurance and Securitization,* 83 AM. J. OF AGRIC. ECON. 656 (2001), http://www.jstor.org/stable/1245095 (last visited Nov. 5, 2022). Mahul's article is a very informative explanation of how risk mutualization and securitization can ensure coverage in the event of a catastrophe; the article primarily deals with natural disasters, but due to the damage scale of those events being comparable to that of a nuclear accident, there is a good deal of applicability to my proposals.

[197] *See* Radetzki & Radetzki, *supra* note 195, at 189.

[198] *See id.* In their paper, Radetzki and Radetzki discuss a hypothetical future for relying on this capital pool to insure against nuclear accident, and I agree with their conceptualization. *See id.* at 189-190.

catastrophe event of a defined magnitude or that causes an aggregate insurance loss more than a stipulated amount.[199] These bonds provide robust layers of protection that make them suitable to cover the risk of nuclear accident.

Some foundational elements of a catastrophe bond scheme must be implemented for this approach to be effective. As Radetzki and Radetzki point out in their 2000 article on private arrangements to cover nuclear accident liabilities:

> …the creation of a market for such bonds presupposes legislation which makes it mandatory for the firms to provide financial guarantees for catastrophe compensation claims. The development of this market also requires clear rules identifying the extent of liability borne by the industrial firm causing a catastrophe, and, by implication, by the catastrophe bond-holders.[200]

However, these necessities are small hurdles to overcome. If sufficient economic inducements exist to promote the nuclear industry, which they already do, then there will also be ample incentives for this type of insurance interaction.

For consumer-company negotiations, nuclear accidents are best classified as a high-dread, low-probability risk. However, individuals' perceptions of risk differ immensely, and that variance heavily informs consumer decisions in my model. Consumers of nuclear power who reside within a probable risk area—which I define as a statistically calculated geographical region surrounding a power plant within which damage from a potential nuclear accident is significantly likely to occur—should perceive two fundamental options in risk-mitigation negotiations with nuclear power companies. The first option would be for consumers to receive electricity for a near-zero price and forego the

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[199] *Insurance Linked Securities*, CTR. FOR INSURANCE POLICY AND RSCH. (last updated October 19, 2021), https://content.naic.org/cipr-topics/insurance-linked-securities [https://perma.cc/T2EG-LCB6]. For more reading on the functioning and history of catastrophe bonds, *see generally* Andy Polacek, *Catastrophe Bonds: A Primer and Retrospective*, CHICAGO FED LETTER, NO. 405 (2018); *see also* Leigh Johnson, *Catastrophe bonds and financial risk: Securing capital and rule through contingency*, 45 GEOFORUM 30 (2013), https://www.sciencedirect.com/science/article/pii/S0016718512000802 [https://perma.cc/6KE7-S444].

[200] Radetzki & Radetzki, *supra* note 195, at 193.

right to sue and to receive compensation for accidents not caused by bad faith or willful neglect. The second option would be for them to retain the right to sue for damages or receive compensation in cases of accidents with any cause but pay full market price for electricity. Consumers could elect either path to effective compensation, basing their decision on their negotiations with their electricity provider.

With the first option, the underlying logic is that the reduced pricing for electricity offsets future damages which remain unlikely to occur. Because the probability of an accident is low over the span of an individual's lifetime and the lifetime of their property, many people would be willing to give up something they may never need (the right to sue and be compensated) in exchange for something they desperately want and need: energy.

In the second option, there would be two categories contributing to damages awarded or settlement compensation offered: property (real and personal) and pain and suffering. The former type would be restricted to the fair market value of the asset at the time of the accident (presuming its total destruction[201]), and the latter would have a statutory definition for the amount to be assessed.

What should the role of the legal system and the judiciary be in this proposed arrangement? The value that the law should provide is rooted in its ability to be foremostly corrective and remedial, rather than preventative. The market can be responsible for deterring harm given the low probability of nuclear accidents. Considering that premise, regulatory law is not the superior answer, and instead, tort law can play a major role given its incorporation into the second negotiation option outlined above.

This type of tort approach is rooted in the concept of environmental common law. As Jason J. Czarnezki and Mark L. Thomsen discuss in their article *Advancing the Rebirth of Environmental Common Law*, "Environmental law and regulation 'has evolved...from reliance on tort law to an emphasis on end-of-pipe controls through direct regulation and finally to an emphasis on pollution prevention.'"[202] Historically, prior to regulations and command and control statutes, the nuisance cause of

[201] As discussed later in this article, there is some potential to stratify damage from nuclear accidents on a scale from temporary to permanent, a judicial decision that could mean that a diminution in value analysis is more appropriate than strict full fair market value compensation.

[202] Jason J. Czarnezki & Mark L. Thomsen, *Advancing the Rebirth of Environmental Common Law*, 34 B. C. ENVTL. AFF. L. REV. 1, 3 (2007), quoting Roger E. Meiners, Stacie Thomas & Bruce Yandle, *Burning Rivers, Common Law, and Institutional Choice for Water Quality, in* THE COMMON LAW AND THE ENVIRONMENT 68 (Roger E. Meiners & Andrew P. Morriss eds., 2000).

action was commonly applied for environmental protection, particularly against pollution.[203] Modern statutory environmental law grew out of the common law tort system, and modern regulations arose in an attempt to deal with inadequacies of the common law.[204] However, as Czarnezki and Thomsen argue, there any many instances in which the common law is still effective for determining appropriate pollution levels, particularly in light of the complexities and bureaucracies of modern environmental regulation.[205] They propose that state common law can be an effective means to prevent and remedy environmental pollution, as well as provide full compensation for harmed victims. It would perform both functions in a superior fashion to federal environmental law.[206] Although nuclear accidents are not discussed in their article, the principles they outline are nonetheless applicable to that scenario.

Tort law has significant natural interactions with economics. As one example, risk in tort law shares many features with economic concepts of risk. One of the implicit principles of tort law is that reducing the probability of an accident to zero is not desirable because it would involve too high a precaution cost—the optimal level of precaution always corresponds to a certain probability of accidents occurring.[207] This is why tort law is a better control on the nuclear industry than regulation. When the probability of a disaster is low, then overregulation stymies the industry by being too precautionary. Tort law, by contrast, accounts for small risks in a way that enables them to be taken and often rewarded with success. In a précis on the economics of tort law, Giuseppe Dari-Mattiacci and Francesco Parisi articulate:

> More specifically, economic analysis suggests that tort law should be designed in such a way as to provide potential injurers and victims with appropriate incentives to avoid the accident by internalizing the externalities created by their activities…Through tort liability, a potential tortfeasor internalizes the benefits of his precaution, that is, the reduction in expected liability. Tort rules should thus be

[203] *See id.* at 4.
[204] *See id.* at 6.
[205] *See id.*
[206] *See id.*
[207] Giuseppe Dari-Mattiacci, *Tort Law and Economics,* UTRECHT UNIVERSITY (Feb. 11, 2003) (https://ssrn.com/abstract=347801).

> designed to induce parties to internalize the external costs of their activities and to adopt optimal levels of precaution. In addition, tort law gives parties incentives to acquire information about the accident.[208]

All these points support my proposed incentive scheme. The Court's logic in *Duke Power Co.* was simply not correct; the PAA is not a sufficient substitute for state law, tort law, and the rational incentives that would otherwise be applied to nuclear power plant developers and operators in its absence. The prescribed amount of recovery under the PAA is not rationally related to the potential losses—not in a Due Process sense, but rather, in terms of economic theory. It is an irrational prescription because the PAA does not rely on a market-established, market-satisfied quantit. A statutory limit on liability does not encourage healthy and efficient private industry participation, although the Court believed it would, because it does not allow for full internatlization of costs. In order to forge a future for nuclear power, the rationality of the legal framework and the proper assumption of responsibility by power plants are critical, and that hinges on calculating damages differently—not from a mere regulatory framework of assumptions, but from the market rate evaluations that are available.

When courts consider damages under my proposal, they should have discretion to assess the impact of a nuclear accident on property on a scale from temporary damage to permanent damage. Temporary damages include displacement of persons for a time while the scale of radiation impact is assessed, and permanent damages include destruction of property by fires caused by a reactor meltdown. A determination of permanent damage would come with an award of the fair market value of the lost property calculated at the time of its destruction. A determination of temporary damage would result in an award based on the diminution in value of the property.[209]

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[208] Giuseppe Dari-Mattiacci & Francesco Parisi, *The Economics of Tort Law: A Precis* 3, *in* THE ELGAR COMPANION TO LAW AND ECONOMICS (2ND ED.) (Edward Elgar Publishing eds. 2006).

[209] However, I must note that in principle I agree with Loyd J. Bourgeois as he writes in his Tulane Environmental Law Journal article: "Ultimately all contamination to land is temporary because technological advancements will render virtually all contamination remediable. Therefore, the questions that must be asked are what price is society willing to pay and how clean is clean?" Loyd J. Bourgeois, *Private Actions Seeking Remediation or Restoration Damages: Who Ensures the Cleanup Actually Occurs*, 17 TUL. ENVTL. L. J. 355, 362 (2004).

Section 929 of the Restatement (Second) of Torts states that a person whose land has been harmed, but not totally devalued, by environmental contamination is entitled to damages amounting to "the difference between the value of the land before the harm and the value after the harm, or at [the owner's] election in an appropriate case, the cost of restoration that has been or may be reasonably incurred."[210] The comments to the section provide that a reasonable cost of replacement to the original condition is generally allowable, but the replacement cost must not be disproportionate to the loss of value.[211] I argue that replacement is a faulty concept in this situation because there is no way to fully provide adequate restoration damages for property lost to a nuclear accident. Psychology informs us that humans develop deep emotional attachments to places and things. Therefore, if something with emotional value is lost, there is no precise way to ever "restore" someone to their pre-loss state, as physical items are defined by far more than their dollar value. However, if we follow the economic principle that individuals are rational actors, then we must say that it is enough to compensate someone in monetary terms for the value of what has been lost, and we must maintain a spirit of optimism that the person who suffered the loss possesses the innate will to make attachments to new things.

Concerning damages for pain and suffering, a statute would restrict those damages to plaintiffs who 1) lived within the prescribed "danger zone" at the time of the accident, and who 2) suffered bodily injury, subject to similar requirements as those existing under the PAA. Notably, I would exclude mental distress from the qualifying forms of suffering for those plaintiffs who functionally consented to live within a statistically likely region of danger. However, I would create a cause of action for those individuals who were temporarily located within the danger zone at the time of the accident and who suffered bodily harm or demonstrable trauma from the immediate event. In either case, the damages would be capped through a calculation of the person's remaining actuarial lifespan. Most importantly, I would recommend a long statute of limitations for bringing these claims, based on current best data about how long it takes for conditions to emerge after exposure to radiation. For example, if someone was exposed to radiation from a nuclear accident, and the resulting symptoms did not emerge for years,

[210] RESTATEMENT (SECOND) OF TORTS § 929 (1979).
[211] *See id.,* cmt. b.

that person would not be barred from recovery if there was clear and convincing evidence of causation.

Even with all the above proposals for reformation, there remains a place for some federal involvement. I have already referred to the need for legislation mandating insurance and defining the catastrophe bonds market There is also a need for federal statute to create a universal definition for standing in tort cases to ensure uniformity across state lines.

Firstly, I propose the ascertainment of a geographical radius around nuclear power plants to classify the persons who can recover in tort suits following a nuclear accident. Per existing standards, mere harm to the environment is not enough to create a basis to bring a tort case; one must prove actual harm to one's person or property.[212] That rule can be extended to this situation to define standing for those who are impacted by an accident in either or both of those two dimensions.

Secondly, there must be a different approach for publically owned property. There is no benefit proceeding from a nuclear power plant to areas of public land in the same way as there is to individual consumers, and calculating the market value of non-privatized lands is an immensely complicated task,[213] making the assessment of any damages a daunting proposition. That predicament is exacerbated by the fact that both economic and non-economic resources are deeply tied to the existence and preservation of public lands.[214] Additionally, all the above facets do not account for the essential considerations of indigenous peoples' land rights and the aspirations for justice in that matter.

This vast topic of ensuring the safety of publicly owned lands, consequently, deserves its own paper to be adequately explored. However, I can summarize its attachment to the proposals of this article by focusing on the aspect of responsibility. Accountability to the state

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[212] As articulated by the Supreme Court in *Massachusetts v. Environmental Protection Agency*, 549 U.S. 497, 517 (2007); the Court therein held that environmental damage could lead to standing for plaintiffs (in this case, the State of Massachusetts) if there was an "actual" and "imminent" injury, regardless of whether the harm could be considered "general." *See* Marisa Martin & James Landman, *Standing: Who Can Sue to Protect the Environment?,* AMERICAN BAR ASSOCIATION (October 9, 2020), https://www.americanbar.org/groups/public_education/publications/insights-on-law-and-society/volume-19/insights-vol--19---issue-1/standing--who-can-sue-to-protect-the-environment-/#:~:text=One%20such%20hurdle%20is%20known,the%20lawsuit%E2%80%94is%20relatively%20straightforward [https://perma.cc/ZNF9-3QU9].

[213] For discussion of this subject, *see generally* Douglas S. Kenney, Gabriel D. Carter & Joshua M. Kerstein, *Values of the Federal Public Lands*, *in* WESTERN LANDS REPORT (Natural Resources Law Center, UNIV. OF COLO. SCH. OF LAW 1998).

[214] *See* Charles F. Wilkinson, *The Public Trust Doctrine in Public Land Law*, 14 U.C. DAVIS L. REV. 269, 269-71 (1980).

and federal governments seems appropriate to ensure that plant operators grasp the significance of the duty they owe to the people. Taxpayers, being the group who stand to benefit from normal power plant operations and who would bear a real social cost in the event of a cleanup, are the ones who have the most compelling interest in the land at issue. Thus, the necessary accountability could take the form of taxes held in a reserve for the life of a nuclear power plant as a hedge against the damages that could come from a nuclear accident. That being said, even in the event of an accident that compromised publicly owned land, a few decades of avoidance[215] is unlikely to be a heavy burden, particularly given the great social benefits afforded by nuclear power.

Thirdly, there is a pressing consideration of damages to natural resources. The District of Columbia Circuit addressed the question of what damage to natural resources may entail in *Ohio v. United States Dept. of the Interior*. The approach of following the common law by taking the lesser of restoration or replacement costs and diminution in value for damage to natural resources was rejected by the court.[216] The original regulations favored market-based techniques over other approaches, preferring use value to non-use value in determining loss. But the *Ohio* holding suggests that restoration costs will provide the presumptive measure of damages for a natural resource harmed by contamination.[217] The use of restoration damages in this way is acceptable given that the purpose of such recovery is to finance the physical restoration of the contaminated area.[218] In my proposed scheme, this sector may be a place for the NRC to continue operations by facilitating and setting cleanup standards. Cases where the environmental impact of a nuclear accident crosses state lines would be particularly consistent with this idea, as the NRC would be able to ensure cooperation, coordination, and uniformity of approaches between the state actors. Beyond this, an analysis of the significance of the economics of conservation would extend outside the scope of this paper. However, it is sufficient to say that emerging trans-disciplines such as ecological economics and environmental management are capable of producing a

[215] For example, it is safe to visit the Chernobyl area, and some residents have even returned to their homes, a choice which is unlikely to be fatal or even unduly dangerous, as studies have been unable to link any direct increase in cancer risks to chronic low-level exposure. *Frequently Asked Chernobyl Questions*, INT'L ATOMIC ENERGY AGENCY, https://www.iaea.org/newscenter/focus/chernobyl/faqs [https://perma.cc/G8GD-DTGX].
[216] Kathryn Chelinda MacDonald, *The Recovery of Restoration Costs: Analytical Synthesis of Common-Law Property Damages, Restitution, and Natural Resource Damages under CERCLA*, 5 TUL. ENVTL. L. J. 255, 270 (1991).
[217] *See id.* at 270-271.
[218] *See id.* at 274.

market-conducive solution to the dilemma of how to ensure that nuclear power plants do not unduly compromise ecosystems and resources while remaining freely profitable.

As a final note, there may be a place for some degree of regulatory authority in the nuclear power industry, notwithstanding the previous point. There is some logic to the claim that federal regulation can standardize the industry and provide a firm set of constraints that are better than what the market may be able to immediately create. Regulatory reform would certainly generate cost savings relative to the current regulatory scheme,[219] and not every iteration of regulatory authority is so overreaching that it inherently discourages innovation and stifles industry. However, the current regulations on the nuclear power industry do stifle growth by raising costs in every area of development and production. Therefore, it is time to overhaul the system to forge the future.

B. Addressing Concerns

Aside from the danger regarding the use and development of nuclear power, cost is among the foremost concerns. Nuclear power has low operating costs, which can make it competitive with the currently popular fossil fuels, and the capital investment needed to open a plant can be recovered over the plant's lifetime.[220] However, the initial investment cost is unavoidably high at present,[221] and the burden of keeping up with the current regulatory requirements is substantial.[222] To the latter consideration, I have already argued that regulations must be repealed in favor of flexible and industry-friendly market forces. If that cost factor is removed, the capital pool for the nuclear energy sector will increase, meaning that nuclear power companies will have the financial assets required to open plants and to innovate for safety.

Innovation will solve the rest of the cost problem. As John Pecman, Commissioner of Competition for the Global Competition Review, has

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[219] *See* Canterbery, *supra* note 15.

[220] Ernest Moniz, *Why We Still Need Nuclear Power: Making Clean Energy Safe and Affordable,* 90 FOREIGN AFFAIRS NO. 6, 83, 88 (2011), (http://www.jstor.org/stable/23039631).

[221] *See* Jason Deign, *MIT Study Lays Bare Why Nuclear Costs Keep Rising,* GREEN TECH MEDIA (December 8, 2020), https://www.greentechmedia.com/articles/read/mit-study-lays-bare-why-nuclear-costs-keep-rising [https://perma.cc/WHH7-6H4T]. As the article points out, though, SMRs may ameliorate this issue. It is worth noting that in countries where continuous development programs have been maintained, capital costs have been contained (and even reduced in South Korea). *Economics of Nuclear Power*, WORLD NUCLEAR ASS'N (last updated August 2022), https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx [https://perma.cc/4EMZ-83BE].

[222] *See* Moniz, *supra* note 220, at 85.

said, "[c]ompetition is a key driver of innovation. In open and competitive markets, firms are driven to adopt more efficient production processes, and to offer new and improved products and services to customers."[223] Innovation will make nuclear power generation cheaper and more efficient, and with reductions in regulations, the capital costs involved in constructing a nuclear power plant would be minimized. In addition, operating costs would be further reduced, making nuclear power a significantly less capital-intensive industry. This would pave the path to a sustainable future.

In the minds of the general population, though, industry costs are not the primary concern when it comes to nuclear power. There is a prevalent fear of nuclear accidents, which is evident given the results of the surveys of Japanese citizens (who, in the wake of disruption to their lives following Fukashima, have largely become wary of nuclear technologies[224]) and considering the long-lasting psychological effects caused by the Chernobyl disaster.[225] However, even as economic incentives can impose needed controls on the nuclear power industry, they can also motivate consumers and citizens to accept the presence of nuclear power plants. In my model, many consumers would probably elect to receive the discounted electricity price because immediate relief from expenditure would be attractive, particularly given the low—and, if sufficient innovation can occur, decreasing—probability of a disaster. Economic models assume that each actor will make rational choices that maximize utility. Surveys have shown that Americans view economic stressors as a highly affective and immediate risk, while environmental risks rank lower.[226] While these surveys have not contrasted economic indices with risk of nuclear accident, they yielded survey results that show acceptance of nuclear power.[227] Americans would likely consider the benefits of nuclear power to be greater than the risks if they were presented with an expansionary plan. As nuclear power is destigmatized and its utility is proven, that acceptance proportion will probably increase.

Though the chance of reactor meltdown and related incidents is low, it is never zero. It is hardly adequate reassurance to say that another

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[223] *Does Competition Drive Innovation?* EDISON AWARDS NEWS, https://edisonawards.com/news/competition-drive-innovation/ [https://perma.cc/CX9A-B9JC].
[224] *See* Kato, *supra* note 104.
[225] *See* USNRC, *supra* note 75.
[226] Nicolas Mertz, *Economic Incentives: Or How I Learned to Stop Worrying and Accept Nuclear Power,* 98 B.U. LAW REV. 1067, 1090 (2018), (https://www.bu.edu/bulawreview/files/2018/10/MERTZ.pdf).
[227] *See* Bisconti, *supra* note 110.

Chernobyl or Fukushima disaster is highly unlikely. While there remains any probability of such an occurrence, fear and distrust of nuclear power will persist. However, there are ways to account for this trepidation and the risks, and one way may be to preserve a role for the NRC. That organization could be reformed to focus solely on research and data collection while maintaining a board of experts qualified to testify regarding safety and probabilities in cases of accidents. Those experts could also be relied upon as a resource to inform the development of power plants and reactors generally.

There is a predictable general counterargument to the proposals of this article. In the absence of governmental controls, the nuclear power industry will have incentives to coordinate their actions in bad faith, aiming to find ways around the requirements generated by insurance companies and thereby shirking their duty to maintain site safety. However, fears of this kind of market failure, as well as other variants, stand on an inadequate foundation; "government failure" is as real a threat as market failure, and bad outcomes often arise not because markets fail, but because they are absent. Furthermore, clear property rights and contracts can open the way for mutually beneficial trade.[228] Nobel Prize-winning economist Ronald Coase observed that, absent transaction costs, externality problems can be traded away in markets.[229] Coase implied that simply taxing or subsidizing various activities based on who caused them often does not lead to efficient results, and he argued that instead of trying to replicate a theoretical ideal market through taxes or subsidies, governments should instead assess means of reducing transaction costs, using direct interventions only if that approach proves futile.[230] Following Coase's conclusions, concerns over externalities, monopolies, and other traditional market failures should not lead to a presumption of a need for federal involvement in nuclear power, and they should not lead to *ex ante* regulations.

V. CONCLUSION

Nuclear power, for all the potential pitfalls and the real dangers it presents, maintains standing as the foremost energy source of the future

[228] Ryan Bourne, *How 'Market Failure' Arguments Lead to Misguided Policy*, CATO INSTITUTE POLICY ANALYSIS NO. 863 (January 22, 2019), https://www.cato.org/policy-analysis/how-market-failure-arguments-lead-misguided-policy [https://perma.cc/LWU3-5N9C].
[229] *See id.*
[230] *See id.*

to achieve the goal of mitigating climate change and supplying ample quantities of consistent electricity. However, the best way to achieve safety and efficiency in nuclear power plants is to remove the constraints of federal statutory-based and agency-imposed regulations. This will allow for key innovation in reactor technologies and ensure that the future of the industry rests securely in appropriate parameters set by the market and consumers.

Of course, in lieu of federal regulatory laws, some form of regulation is needed to ensure safety standards across the industry and to provide for frightened citizens and consumers of nuclear-generated electricity. However, such controlling parameters will naturally emerge if market forces are allowed to function freely in this sector.

Consumers and nuclear power companies should be able to negotiate between two fundamental options: the consumer receiving near-zero-priced electricity in exchange for an agreement not to sue if a nuclear accident occurred, or the consumer receiving market-pricing for electricity with retention of the right to sue for damages and be compensated for the damages from an accident. In a revision of the insurance scheme, catastrophe bonds should play an important role in creating a resource pool large enough to account for the potential scale of a nuclear accident. Finally, for those customers who elect to retain their right to sue, tort damages should be seen as the optimal remedy in those cases of disaster.

With this approach, nuclear power will fulfill the energy needs of the U.S., and it will benefit the entire world by reducing the energy sector's climate impact. To borrow Grossman's language, nuclear power is "one hell of a way" to secure the future, and the U.S. should be a global leader in its innovation and implementation.