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Reviving Spent Nuclear Fuel Reprocessing in the U.S.

Emily M. Farah

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INTRODUCTION

Nuclear power generation is responsible for fifteen percent of the world's electricity, and since the beginning of the century additional nuclear reactors have appeared on the global grid in places other than the United States and Europe.[1] Currently, sixty one nuclear reactors are under construction, and three-quarters of those are located in four countries: China, India, South Korea, and Russia.[2] China aims to quadruple its nuclear power capacity by 2020. The United Arab Emirates entered into a 20 billion dollar contract with a South Korean consortium to build four nuclear reactors expected to be operational in 2017.[3] Additionally, Finland is building two nuclear reactors.[4] France, which is responsible for about half of Europe's total nuclear power generating capacity, is currently building one "massive" new nuclear reactor.[5] Although some countries, like Italy and Germany, have moratoriums on new nuclear power, those countries still import a good percentage of nuclear-generated electricity from the world's largest exporter of electricity—France.[6]

Nuclear power creates radioactive waste with a half-life that spans thousands of years.[7] If nations could reduce the radioactivity and volume, and thus the potential

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[1] DANIEL YERGIN, THE QUEST: ENERGY, SECURITY, AND THE REMAKING OF THE MODERN WORLD 413 (2012).

[2] *Id.*

[3] *Id.*

[4] *Id.* at 414.

[5] *Id.*

[6] *Id.* at 416.

[7] Aaron Szabo, *Reprocessing: The Future of Nuclear Waste*, 29 TEMP. J. SCI. TECH. & ENVTL. L. 231, 233 (2010) (discussing the half-life of an atom or compound is its rate of deterioration).

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harmfulness, of nuclear waste by recycling spent nuclear fuel, would they take this opportunity? In the United States, the answer is no. In France, however, the answer is yes. The purpose of this paper is not to advocate for or condemn the use of nuclear technology. It will not delve deeply into the full meltdowns at nuclear reactors in Chernobyl and Fukushima, or the partial meltdown at Three Mile Island[8] because those accidents, while significant and should not be understated, illustrate the risks involved with nuclear power generation and the devastation that results if something goes wrong. Instead, this note evaluates why the United States does not reprocess spent nuclear waste, why it is important to revive reprocessing to reduce overall environmental impact, and how the nation can implement a reprocessing program through education, proper marketing, and governmental assistance.

Section I discusses the technicalities of nuclear power generation. It will explain how electricity is created via nuclear fission, how spent nuclear fuel can be reprocessed, and how nuclear waste presents different types of harms. Section II explores the history of nuclear power regulation in the United States, including the country's original plan to reprocess fuel, its back-up plan to build a repository, and its current interim fuel storage in dry casks. Section III will discuss France's reprocessing approach and conclude that the United States should adopt France's sustainable model for reprocessing nuclear fuel.

I. NUCLEAR POWER GENERATION

Nuclear energy is created in most power plants by heating water and turning it into high-pressure steam, which drives turbine generators.[9] The rotation of the turbine generators through a magnetic field produces electricity. The key difference between fossil-fueled power plants and nuclear power plants is how the water is heated.[10] In fossil-fueled power plants, coal, oil, or natural gas is burned to create heat.[11] In a nuclear power plant, however, the heat is produced through fission,[12]

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[8] *See* Adam Clark Estes, *Fukushima 'Full Meltdown' Made Official*, THE WIRE (May 12, 2011, 7:17 PM), http://www.thewire.com/global/2011/05/fukushima-full-meltdown-made-official/37671/ (stating that whether Fukushima suffered a full or partial meltdown is debatable).

[9] *How Do Nuclear Plants Work?*, DUKE ENERGY, http://www.duke-energy.com/about-energy/generating-electricity/nuclear-how.asp (last visited Sept. 28, 2014).

[10] *Id.*

[11] *Id.*

[12] *Id.*

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which is the splitting of uranium atoms.[13] Therefore, there is no combustion involved in nuclear power plants like there is in fossil-fuel plants.[14]

There are two types of nuclear reactors in the United States that are responsible for creating twenty percent of the nation's energy: pressurized water reactors and boiling water reactors.[15] Out of the approximate one-hundred nuclear reactors in the nation, more than half are pressurized water reactors.[16] In pressurized water reactors, the water is put under an extreme amount of pressure when it is heated, and the water never reaches a boil. Thus, the "heated water is circulated through tubes in steam generators, allowing the water in the steam generators to turn to steam, which then turns the turbine generator."[17] In pressurized water reactors, the water from the reactor and the water that is turned into steam are in separate systems that do not mix.[18]

Contrastingly, in boiling water reactors "the water heated by fission actually boils and turns into steam to turn the turbine generator."[19] This steam has a small level of radioactivity and slightly contaminates sites throughout the plant. Therefore, boiling water reactors pose more risks because there is a higher possibility for dangerous leaks. Other than the way the reactor turns water into steam, pressurized water reactors and boiling water reactors are very similar.

A. The Nuclear Fuel Cycle

The nuclear fuel cycle begins with mining uranium ore out of the earth. Upon extraction, mined uranium is about 99.3 percent "uranium-238," 0.7 percent "uranium-235" (U235), and less than 0.01 percent "uranium-234."[20] Because the fuel for nuclear reactors has to have a higher concentration of U235 than exists in natural uranium ore, uranium must be "enriched" in order for the utility companies to create

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[13] *Id.*

[14] *Id.*

[15] *How Nuclear Reactors Work*, NUCLEAR ENERGY INST., http://www.nei.org/Knowledge-Center/How-Nuclear-Reactors-Work (last visited Sept. 28, 2014).

[16] *How many nuclear power plants are in the United States, and where are they located?*, U.S. ENERGY INFO. ADMIN. (last updated Jan. 27, 2016), http://www.eia.gov/tools/faqs/faq.cfm?id= 207&t=3 [hereinafter *How many nuclear power plants*].

[17] *How Do Nuclear Plants Work?*, *supra* note 9.

[18] *Id.*

[19] *Id.*

[20] *Uranium Enrichment*, U.S. NUCLEAR REG. COMMISSION (last updated Sept. 2016), http:// www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html.

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the fuel for their nuclear reactors.[21] After enrichment, the uranium is manufactured into small, round fuel pellets.[22] The pellets are then inserted into fuel rods, which are about twelve feet long.[23] Roughly two hundred rods are grouped together, referred to as the "fuel assembly," which is inserted into the reactor core.[24] Fission begins when neutrons are introduced: "Once an atom of uranium 235 is split, neutrons from the uranium atom are free to collide with other uranium 235 atoms."[25] This chain reaction generates heat. The chain reaction is managed and maintained in part by "control rods," which absorb excess neutrons that would cause the chain reaction to get out of control.[26] Once the fuel in the rods is spent, it must be replaced. Typically, about one-third of the reactor core is changed every one or two years depending on the design of the reactor.[27]

Following use in the reactor, the fuel rods are still highly radioactive with plutonium and uranium from the fission process. Plutonium is a radioactive byproduct created when the uranium absorbs the neutrons in the chain reaction.[28] Consequently, the rods are stored under water in a spent fuel pool at the reactor for at least three years.[29] The rods must cool because, while the fission has stopped, "the spent fuel continues to give off heat from the decay of radioactive elements that were created when the uranium atoms were split apart."[30] After cooling for several years, the spent fuel will be sealed in a dry storage container, also called a dry cask, on site or at an interim storage facility.[31] Currently, this temporary storage solution is the final step in the United States nuclear fuel cycle because "[t]he United States

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[21] *Id.*

[22] *How Do Nuclear Plants Work?*, *supra* note 9.

[23] *Id.*

[24] *Id.*

[25] *Id.*

[26] *Id.*

[27] *See id.*

[28] Most plutonium is man-made, but it is a naturally occurring element. *See Backgrounder on Plutonium*, U.S. NUCLEAR REG. COMMISSION (last updated Sept. 30, 2015), http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/plutonium.html.

[29] Katherine Ling, *Is the Solution to the U.S. Nuclear Waste Problem in France?*, N.Y. TIMES (May 18, 2009), http://www.nytimes.com/cwire/2009/05/18/18climatewire-is-the-solution-to-the-us-nuclear-waste-prob-12208.html?pagewanted=all.

[30] *The Nuclear Fuel Cycle*, U.S. ENERGY INFO. ADMIN., http://www.eia.gov/energyexplained/index.cfm?page=nuclear_fuel_cycle (last visited Sept. 28, 2014).

[31] *Spent Fuel Storage in Pools and Dry Casks Key Points and Questions & Answers*, U.S. NUCLEAR REG. COMMISSION (last updated Apr. 13, 2015), http://www.nrc.gov/waste/spent-fuel-storage/faqs.html.

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currently has no permanent underground repository for high-level nuclear waste."[32] This "once-through" fuel use is known as an open fuel cycle.[33]

France has a closed fuel cycle.[34] Instead of disposing spent fuel after one use, France transports it to a reprocessing facility where uranium and plutonium are recovered and reused.[35] Used fuel rods retain at estimated ninety percent of their energy value, and "reprocessing, at least in theory, could retrieve a significant amount of energy value for reuse . . . [and] it is not technically impossible to recapture and use all the residual energy value of spent fuel."[36]

B. Reprocessing Spent Nuclear Fuel

As of September 2014, almost 90,000 metric tons of spent fuel from commercial nuclear power reactors has been reprocessed.[37] A variety of methods have been developed, but only one is currently used for commercial reprocessing of spent nuclear fuel.[38] The plutonium and uranium extraction process (PUREX), begins with chopping the fuel rods into "sausage-sized" pieces.[39] Those pieces are dissolved in nitric acid and introduced to an organic solvent.[40] The solvent, usually tributyl phosphate diluted with kerosene, extracts the plutonium and uranium oxides.[41] Then, the extracted plutonium and uranium are separated from each other in the "radioactive soup."[42] The uranium must be re-enriched before being placed into new fuel rods for nuclear power plants, and the plutonium can be turned into Mixed Oxide Fuel (MOX) for use in standard commercial nuclear reactors or into

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[32] *How Many Nuclear Power Plants*, *supra* note 16.

[33] *Recycling Used Nuclear Fuel*, NUCLEAR ENERGY INST., http://www.nei.org/Issues-Policy/Nuclear-Waste-Management/Recycling-Used-Nuclear-Fuel (last visited Nov. 15, 2014).

[34] *See id.*

[35] Ling, *supra* note 29.

[36] RICHARD BURLESON STEWART & JANE BLOOM STEWART, FUEL CYCLE TO NOWHERE: U.S. LAW AND POLICY ON NUCLEAR WASTE 19 (2011).

[37] *Processing of Used Nuclear Fuel*, WORLD NUCLEAR ASS'N (last updated Nov. 2015), http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Processing-of-Used-Nuclear-Fuel/.

[38] Charles de Saillan, *Disposal of Spent Nuclear Fuel in the United States and Europe: A Persistent Environmental Problem*, 34 HARV. ENVTL. L. REV. 461, 479 (2010).

[39] *Id.*; *see also* WILLIAM M. ALLEY & ROSEMARIE ALLEY, TOO HOT TO TOUCH: THE PROBLEM OF HIGH-LEVEL NUCLEAR WASTE 94 (2012).

[40] de Saillan, *supra* note 38, at 479.

[41] *Id.*

[42] *See* ALLEY & ALLEY, *supra* note 39, at 94.

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"Breeder" or "Fast" Reactors, utilized outside of the United States.[43] This process is repeated three times "to attain a high level of recovery," estimated at greater than 99 percent of recovered spent fuel.[44]

However, nuclear reactors cannot operate exclusively using MOX.[45] At most, reactors can use about one-third MOX "due to the different properties of the plutonium in the MOX fuel."[46] After its use in a nuclear reactor, spent MOX fuel is not reprocessed.[47] Instead, it is placed in storage and eventually disposed.[48] A discussion of disposal via dry casks, discussed *infra*.

Ultimately, reprocessing does not eliminate the need for a permanent resting place for radioactive nuclear waste because there are still residual materials that are highly acidic and radioactive.[49] Thus, a reprocessing program in the United States would have to work alongside a permanent repository plan.

C. Types of Nuclear Waste

Simply put, nuclear waste is dangerous because of its radioactivity. Radiation is the result of unstable atoms, called radionuclides, disintegrating spontaneously.[50] If not contained, the radiation can cause health problems, such as cancer, other sickness, and death, and environmental problems, such as ecosystem destruction, animal deformity and even death.[51] The primary concern about radioactive waste is that when it is released into the environment it might be ingested by humans via eating, drinking, or breathing, which would result in "packing a source of radiation very close to vulnerable tissues."[52]

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[43] Unlike conventional reactors, this type of reactor (the "breeder" or "fast" reactor) has no moderator to slow down bombarding neutrons. Martin Peder Maarbjerg, *The Global Nuclear Energy Partnership: Is the Cure Worse Than the Disease?*, 16 U. BALT. J. ENVTL. L. 127, 134 (2009).

[44] de Saillan, *supra* note 38, at 479.

[45] *Id.*

[46] *Id.*

[47] *Id.*

[48] *Id.*

[49] *Id.*; *see also* YERGIN, *supra* note 1, at 410.

[50] *Environmental and Health Effects of Nuclear Waste Dumping in the Arctic*, PRINCETON UNIVERSITY 2, https://www.princeton.edu/~ota/disk1/1995/9504/950405.PDF (last visited Oct. 10, 2016).

[51] *Id.*

[52] ALLEY & ALLEY, *supra* note 39, at 56.

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Generally, there are three types of radioactive waste: low-level, intermediate-level, and high-level. Low-level waste is usually found in hospitals and laboratories from things like rags, tools, paper, and clothing.[53] Although those objects contain a small amount of short-lived radioactivity and are not dangerous to handle, they must be disposed of more carefully than regular garbage. As such, low-level waste is usually compacted or incinerated before disposal.[54] The vast majority—90 percent—of the world's radioactive waste is low-level waste. Despite the volume, low-level waste is not the main source of radioactivity. In fact, it is only responsible for one percent of the radioactivity emitting from the world's radioactive wastes.[55]

In contrast, intermediate-level waste is less prevalent but more radioactive. Worldwide, intermediate-level waste is responsible for seven percent of the volume and four percent of the radioactivity produced by all radioactive wastes.[56] Because intermediate-level waste contains higher amounts of radiation, it might require special shielding before handling; however, the radioactivity in intermediate-level waste created by nuclear reactors is generally short-lived.[57] For disposal, intermediate-level waste is usually solidified in concrete or bitumen and buried underground.[58]

Finally, high-level waste is either the spent fuel itself or the materials left over after the spent fuel is reprocessed.[59] While only three percent of the volume of all radioactive waste, it is responsible for 95 percent of the radioactivity because it "contains the highly-radioactive fission products and some heavy elements with long-lived radioactivity."[60] As such, high-level radioactive waste generates heat and requires cooling and must be handled with special shielding at all times.[61] Although high-level waste is extremely radioactive, if it is reprocessed and reused in the

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[53] *Waste Management Overview*, WORLD NUCLEAR ASS'N, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx (last visited Sept. 19, 2016).

[54] *Id.*

[55] *Id.*

[56] *Id.*

[57] *Id.*

[58] *Id.*

[59] *High-Level Waste*, U.S. NUCLEAR REG. COMMISSION (last updated Apr. 8, 2015), www.nrc.gov/waste/high-level-waste.html.

[60] *Waste Management Overview*, *supra* note 53.

[61] *High-Level Waste*, *supra* note 59.

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nuclear fuel cycle, its radioactivity diminishes.[62] Additionally, after roughly a hundred years, the radioactivity of reprocessed high-level waste falls much more rapidly compared to spent fuel that has not been reprocessed.[63] The disposal capsules for high-level waste vary depending on whether used fuel is reprocessed.[64] If the used fuel is reprocessed, the separated waste is vitrified by incorporating it into Pyrex glass, sealed inside stainless steel canisters, and disposed deep underground.[65] However, if spent fuel is not reprocessed, all of the highly radioactive isotopes remain in it, causing the entire fuel assembly to be treated as high-level waste.[66] Disposing the entire fuel assembly consumes about nine times the volume of the vitrification method, discussed *infra*.[67]

II. U.S. REGULATORY HISTORY OF NUCLEAR POWER

To understand why the United States does not recycle spent nuclear fuel despite its multiple benefits, it is important to understand the development of nuclear technology regulation. The devastating power of nuclear technology was first demonstrated in World War II, when the United States dropped two atomic bombs on Hiroshima and Nagasaki.[68] Congress then adopted the Atomic Energy Act of 1946 (AEA). The AEA created the Atomic Energy Commission (AEC) to control nuclear technology, creating a federal monopoly on all applications of nuclear activity.[69] As the Cold War began, the AEC focused most of its attention on nuclear weapons, but it was also in charge of developing nuclear reactors to generate electricity for the public.[70]

The shift away from military control to the private sector began with President Eisenhower's 1953 Atoms for Peace initiative, which allowed the private sector to construct, own, and operate nuclear generating plants under the supervision and regulatory scheme of the AEC.[71] In 1954, Congress amended the AEA to authorize

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[62] *Processing of Used Nuclear Fuel*, *supra* note 37.

[63] *Id.*

[64] *Waste Management Overview*, *supra* note 53.

[65] *Id.*

[66] *Id.*

[67] *Id.*

[68] JOSEPH P. TOMAIN & RICHARD D. CUDAHY, ENERGY LAW IN A NUTSHELL 456 (2d ed. 2011).

[69] STEWART & STEWART, *supra* note 36, at 18.

[70] *Id.*

[71] *Id.*

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and regulate civilian uses of nuclear materials.[72] The purpose of the 1954 AEA was "to provide for 'a program to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes to maximum extent consistent with the health and safety of the public.'"[73] The initial attempt to encourage public and private sectors to compete for nuclear business was unsuccessful because most companies were not willing to bear the burden if there were an accident. In fact, "[o]fficials of General Electric, one of the major reactor builders, threatened to withdraw from nuclear development activity, stating that GE would not proceed 'with a cloud of bankruptcy hanging over its head.'"[74] As a response, Congress passed the Price-Anderson Act of 1957 (PAA), "which limited industry liability while assuring some compensation for the public in the event of a nuclear accident."[75] The act limited a public utility's financial exposure in the event of a nuclear incident.[76] The PAA became law in 1957, and the private sector began diving into the nuclear power generation business. The PAA was renewed every ten years until the 2005 Energy Policy Act extended the act to 2025.[77]

After nuclear power generation was opened to the private sector, the conflicting objectives of the AEC caused public perception issues.[78] The AEC promoted the use of nuclear power as well as ensued that the technology was applied safely.[79] Therefore, Congress split the AEC into two entities: the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA). By passing the Energy Reorganization Act of 1974, Congress established the NRC as an independent agency responsible for safety and licensing.[80] The ERDA, later absorbed by the Department of Energy, was responsible for research and development.[81] However, the split has not completely resolved the issue of conflicting functions within the NRC.[82] Currently, the NRC is responsible for

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[72] *Id.*

[73] TOMAIN & CUDAHY, *supra* note 68, at 433.

[74] *Id.* at 434.

[75] *Id.*

[76] *Id.*

[77] *Id.*

[78] TOMAIN & CUDAHY, *supra* note 68, at 436.

[79] *Id.*

[80] *Id.*

[81] *Id.*

[82] *Id.*

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licensing and safety oversight.[83] Thus, if the NRC too vigorously exercises its safety role, then "the attendant compliance costs could act as a disincentive to invest in nuclear plants."[84]

As part of the NRC's reactor licensing process, it conducts an extensive site evaluation. The NCR assesses seismology, geology, and hydrology, among other issues, and grants a license only when there is a "reasonable assurance" that the nuclear power reactor can be constructed and operated without "undue risk" to public health and safety.[85] Licensees are also required to file an environmental report, and show that they have the financial wherewithal for decommissioning and operation of the plant.[86]

The Energy Policy Act of 1992 contained several new provisions affecting nuclear power, including provisions that streamlined the licensing process.[87] Previously, one license was needed for construction while another was needed for operation; however, under the Energy Policy Act, only one license is necessary.[88] The Energy Policy Act also supported research for new reactor technologies and addressed permanent high-level waste storage.[89] In February 2012, the Obama Administration, through the Energy Policy Act of 2005, announced loan guarantees to the Southern Company and its partners to build two nuclear plants in Georgia.[90] These plants are the first to be built in the United States in decades.[91] In addition to federal loan guarantees, the 2005 Energy Policy Act also provides tax incentives for the first six gigawatts of nuclear capacity to come online by 2020.[92] The first six projects are also eligible for "several hundred million dollars of federal funds to compensate them for any 'breakdown in the regulatory process' or litigation."[93]

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[83] *Id.*

[84] TOMAIN & CUDAHY, *supra* note 68, at 436.

[85] North Anna Envtl. Coal. v. U.S. Nuclear Regulatory Comm'n, 533 F.2d 655, 664 (D.C. Cir. 1976).

[86] 10 C.F.R. § 50; *see also* TOMAIN & CUDAHY, *supra* note 68, at 436.

[87] *Id.*

[88] *See supra* note 87.

[89] *Id.*

[90] YERGIN, *supra* note 1, at 408.

[91] *Id.*

[92] *Id.* at 409.

[93] *Id.*

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A. Plan A: Reprocessing Nuclear Fuel

According to Larry Brown, a professor at George Washington University School of Law, reprocessing spent nuclear fuel was "Plan A," and building a repository was "Plan B."[94] However, the initial reason for reprocessing was not environmentally motivated.[95] Instead, there was presumption that there would be a shortage of uranium, and reprocessing offered a way to conserve it.[96] Brown explains, "[i]t was believed that easily recovered, and thus low cost, uranium reserves would be exhausted within a few decades by a rapidly expanding nuclear industry."[97] Three reprocessing plants were built in the United States, but only one, in West Valley, New York, became operational.[98] The West Valley reprocessing plant "reprocessed commercial used fuel and some defense fuel, but when it shut down for maintenance and repairs the costs exceeded expectations and [it] was never restarted."[99] General Electric attempted to run a reprocessing plant, called the "Midwest Fuel Recovery Plant" in Morris, Illinois.[100] It was built in 1974, and cost $64 million to build.[101] It operated for twenty-six hours, but due to technical problems and equipment failures the facility was deemed inoperable and shut down in 1974.[102] Another reprocessing facility, the Barnwell Plant was built by Allied General Nuclear Services in 1970 in Barnwell, South Carolina.[103] But, it was not completed by the time President Carter halted funding reprocessing in 1977 and was never operational.[104]

The Carter Administration should not shoulder all the blame for stopping reprocessing in the United States. In October 1976, President Gerald Ford halted reprocessing programs in a comprehensive speech on nuclear policy,[105] and Carter

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[94] E-mail from Larry Brown, Professor, George Wash. Univ. Sch. of Law, to author (Oct. 26, 2014, 17:49 EST) (on file with author).

[95] STEWART & STEWART, *supra* note 36, at 46.

[96] *Id.*

[97] ALLEY & ALLEY, *supra* note 39, at 97.

[98] Brown, *supra* note 94.

[99] *Id.*

[100] STEWART & STEWART, *supra* note 36, at 45.

[101] *Id.*

[102] *Id.*

[103] *Id.* at 46.

[104] *Id.*

[105] President Gerald R. Ford, Presidential Statement on Nuclear Policy (Oct. 28, 1976), http://www.presidency.ucsb.edu/ws/?pid=6561.

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simply continued the moratorium. Ford's speech made no mention of environmental issues.[106] At the time, the primary concern was weapons proliferation.[107] A likely motivator for this concern was a clear abuse of nuclear technology. In 1974, India "shocked the world and embarrassed the United States by successfully testing a nuclear weapon made with plutonium produced by reprocessing [spent nuclear fuel] from a reactor brought from Canada that used uranium," and to make matters worse, the reprocessing facility was built based on training provided by the United States.[108] To this day, India is not a part of the Non-Proliferation of Nuclear Weapons Treaty (NPT), which aims to prevent the spread of nuclear weapons and weapons technology, promote cooperation in the peaceful uses of nuclear energy, and further the goal of nuclear disarmament.[109] The NPT is the "only binding commitment in a multilateral treaty to the goal of disarmament by the nuclear-weapon States."[110] It was originally opened for signature in 1968, and indefinitely extended in 1995.[111] Almost two hundred parties have joined the NPT, including the United States and the four other nuclear weapon States.[112] Interestingly, more countries have ratified the NPT than any other arms limitation and disarmament agreement.[113] The United Nations agency responsible for the NPT, the International Atomic Energy Agency (IAEA), "has not imposed any universal prohibitions on commercial reprocessing plants and provides strict safeguards and guidelines on building and using reprocessing plants."[114] Because the NPT is silent on reprocessing, it allows both non-nuclear and nuclear nations to develop reprocessing plans.[115]

During President Reagan's term, the moratorium on reprocessing was lifted, but by then, the focus was on "Plan B," the Nuclear Waste Policy Act, and building a repository.[116] However, this means that there was, and currently remains, no law

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[106] *Id.*

[107] STEWART & STEWART, *supra* note 36, at 46.

[108] *Id.*

[109] Treaty on the Non-Proliferation of Nuclear Weapons, *opened for signature* July 1, 1968, 21 U.S.T. 483, 729 U.N.T.S. 161, https://www.un.org/disarmament/wmd/nuclear/npt.

[110] *Id.*

[111] *Id.*

[112] *Id.* The five nuclear weapon states, all permanent members of the UN Security Council, are: United States, Russian Federation, United Kingdom, France, and China. *See generally* www.un.org.

[113] Treaty on the Non-Proliferation of Nuclear Weapons, *supra* note 109.

[114] Szabo, *supra* note 7, at 243.

[115] *Id.*

[116] Brown, *supra* note 94.

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against reprocessing in the United States.[117] Without an obstacle to reprocessing, Department of Energy (DOE) Secretary Clay Sell announced the Global Nuclear Energy Partnership (GNEP) in 2006.[118] The purpose of the GNEP was to bring back nuclear energy on a large scale, and at the heart of the GNEP was the Bush Administration's plan to encourage reprocessing.[119] An integral part of the GNEP would have the United States reentering the uranium business by "joining with other [reprocessing] countries, such as Russia, the United Kingdom, France, and Japan, to provide enriched uranium obtained through reprocessing [spent nuclear fuel] to nations that want to develop commercial nuclear power, without their having to construct either uranium enrichment or reprocessing facilities."[120] The nations seeking to develop commercial nuclear power would presumably be developing countries, and a cause for concern in the GNEP proposal was that it did not address whether the materials produced by reprocessing would stay in the developed nations that had the reprocessing facilities or the developing countries that had the spent nuclear fuel to reprocess.[121] As such, the developed countries might have had to agree to handle all the waste in order to obtain the participation of developing countries.[122]

The GNEP also proposed a different reprocessing method: the UREX+ fuel cycle.[123] Like the PUREX process, UREX+ would separate uranium isotopes, but would then separate out two other highly radioactive fission products—strontium (Sr-90) and cesium (Cs-137)—which are the "main sources of radioactive decay heat in a repository for several hundred years."[124] Once separated, the strontium and cesium would be placed in surface containers near the reprocessing facilities for several centuries until it decayed enough to be considered low-level waste.[125] By removing strontium and cesium from the wastes to be disposed at Yucca, the DOE claimed that there would be a twenty-fold reduction in the long-term temperature

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[117] *Advanced Fuel-Cycle Technologies Hold Promise for Used Fuel Management Program*, NUCLEAR ENERGY INST. (June 2013), http://www.nei.org/CorporateSite/media/filefolder/Backgrounders/Policy-Briefs/Advanced-Fuel-Cycle-Technologies-Hold-Promise-for-Used-Fuel-Management-Program-June-2013.pdf?ext=.pdf.

[118] STEWART & STEWART, *supra* note 36, at 246.

[119] *Id.*

[120] *Id.*

[121] *Id.* at 247.

[122] *Id.*

[123] *Id.*

[124] STEWART & STEWART, *supra* note 36, at 247.

[125] *Id.*

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decrease in the rock surrounding Yucca Mountain.[126] If reprocessing were implemented under the GNEP, the NRC would most likely have exclusive jurisdiction over the processes.[127] However, waste management and disposal would be subject to the Environmental Protection Agency's (EPA) radiation standards.[128]

In 2009, the Obama Administration zeroed-out funding for the GNEP, but the organization still meets as an international network without the full support of the United States.[129] In 2010, the members changed the name to the International Framework for Nuclear Energy Cooperation, and changed its mission, "in order to broaden its scope and increase international participation," and create a forum for international cooperation in the peaceful uses of nuclear energy.[130]

B. Plan B: Building a Repository

The legislative record for "Plan B" began when Congress enacted the Nuclear Waste Policy Act (NWPA) in 1982.[131] The NWPA mandated that the Department of Energy implement a blueprint for the repositories and established a goal for the federal government to take over wastes by 1998.[132] In 1987, Congress designated Yucca Mountain in Nevada as the national repository, but the Obama Administration has since terminated the Yucca Mountain repository's license.[133] However, the DOE authority to withdraw the Yucca Mountain license from the NRC has been challenged and is currently being litigated.[134] Even if courts decide that the NWPA does not allow the DOE to prohibit the licensing of Yucca Mountain, there will still be challenges.[135] For example, Congress, which has previously refused to appropriate monies for Yucca Mountain project, would have to find a way to fund it.[136] This leaves the country without any long-term plan or back-up plan for radioactive waste.[137] Even if Yucca Mountain ultimately receives a license from the NRC and

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[126] *Id.*

[127] *Id.* at 248.

[128] *Id.*

[129] *Id.* at 252.

[130] *Id.*

[131] STEWART & STEWART, *supra* note 36, at 190–92.

[132] *Id.*

[133] STEWART & STEWART, *supra* note 36, at 187.

[134] *Id.* at 228–29.

[135] *Id.* at 229.

[136] *Id.*

[137] *Id.* at 230.

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becomes operational, it is not big enough to store all of the nation's nuclear waste.[138] According to the Nevada Attorney General, seventy-seven reactor sites across the country are holding 70,000 metric tons of high-level nuclear waste and spent nuclear fuel, and estimates that each site accumulates 2,000 tons each year.[139] Yucca's design capacity is only 77,000 metric tons. Thus, by the time Yucca Mountain would be filled to capacity in 2036, "there will still be at least the same amount of spent fuel still stored at the reaction sites, even if no new plants are built."[140] This, however, might be resolved if reprocessing was implemented.

President Obama has strongly supported the expansion of nuclear power in the United States to combat climate change and boost the nation's economy,[141] a position which is directly at odds with his plan to terminate Yucca Mountain's license. Without Yucca or another long-term repository, states are likely to block the expansion of nuclear power.[142] Representative Mike Simpson, an Idaho Republican, recently commented that Yucca Mountain "is going to be dead" if it does not get support from the incoming 2016 presidential administration.[143]

If a repository were opening soon, in Yucca Mountain or elsewhere, it would be imperative that the "reprocessing and retrieveability issue" be resolved quickly.[144] The NWPA requires that spent nuclear fuel placed in a repository be retrievable within fifty years from the date the repository begins receiving waste "for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel."[145] Because the United States has not implemented reprocessing, a repository's design would not incorporate long-term retrieveability of spent nuclear fuel. This is economically problematic because if the nation allows reprocessing, the costs associated with retrieving spent fuel would increase significantly if the repository's

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[138] Szabo, *supra* note 7, at 240.

[139] *The Fight Against Yucca Mountain*, NEVADA ATTORNEY GENERAL, http://ag.nv.gov/Hot_Topics/Issue/Yucca (last visited Nov. 19, 2014).

[140] *Id.*

[141] STEWART & STEWART, *supra* note 36, at 257.

[142] *Id.*

[143] Rebecca Kern, *Yucca Is Dead If Nixed by New Administration: Rep. Simpson*, BLOOMBERG GOVERNMENT, https://about.bgov.com/blog/breaking-decoder-ring-trump-rfs/ (last visited Sept. 19, 2016).

[144] STEWART & STEWART, *supra* note 36, at 268.

[145] *Id.* at 190, 268; *see also* 42 U.S.C. § 10142 (2012).

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design and construction do not facilitate retrieveability.[146] It is important that reprocessing is considered in the repository's design phase so that the repository's design is conducive to retrieving spent nuclear fuel. For example, France's permanent repository, which is sited within a solid argillite formation, is designed with the goal of ensuring retrieveability for one hundred years.[147]

C. The Plan . . . For Now

Because spent nuclear fuel has accumulated without a permanent repository, the NRC has authorized nuclear facilities to fill their pools with five times the amount allowed in their original licenses.[148] This is worrisome, considering that a compromised spent fuel pool created the disaster in Fukushima.[149] As of 2009, eighty-five percent of accumulated spent nuclear fuel was being held in fuel pools.[150] The remaining spent fuel is stored on-site in "dry casks."[151] The NRC currently licenses for dry cask interim storage every twenty years.[152]

NRC-certified casks usually have an outer layer and inner layer.[153] The inner layer is reinforced stainless steel and looks like a "giant metallic thermos."[154] It is fourteen feet long and three feet wide.[155] The outer layer is a thick concrete surrounding the inner canister.[156] Dry casks are designed to contain radiation, manage heat, prevent nuclear fission, and resist earthquakes, projectiles, tornadoes, floods, temperature extremes, and natural disasters.[157] Additionally, dry casks are constantly monitored.[158] Fully loaded, the casks weigh about one hundred tons.[159]

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[146] STEWART & STEWART, *supra* note 36, at 190, 269.

[147] *Id.*

[148] *Id.* at 46.

[149] Malcom Grimston, *Fukushima: What happened—and what needs to be done*, BBC NEWS (last updated Apr. 11, 2011), http://www.bbc.co.uk/news/world-asia-pacific-13017282.

[150] STEWART & STEWART, *supra* note 36, at 79.

[151] *Id.*

[152] *Id.* at 80.

[153] ALLEY & ALLEY, *supra* note 39, at 115.

[154] *Id.*

[155] *Id.*

[156] *Id.*

[157] *See Dry Cask Storage*, NUCLEAR REG. COMMISSION (last updated July 21, 2016), http://www.nrc.gov/waste/spent-fuel-storage/dry-cask-storage.html.

[158] *Id.*

[159] ALLEY & ALLEY, *supra* note 39, at 115.

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Dry cask storage is considered safe and environmentally sound,[160] but only fifteen percent of the spent nuclear fuel is being stored at reactor sites in dry casks.[161]

The Idaho National Laboratory conducted a study in 2001, which involved the inspection of a dry cask that had been loaded with spent fuel assemblies since 1985.[162] *The Dry Cask Storage Characterization Project* concluded that the cask performed well over a fifteen-year period, but the inspections also exposed a number of vulnerabilities.[163] First, the study only inspected the outer concrete structure of the cask and neglected to look on the inside, "where the action is."[164] Second, the fuel rods inside the cask were in "mint condition," which is problematic because some sites store damaged fuel rods.[165] Third, it is estimated that today's nuclear fuel is "much hotter and more radioactive" than the fuel in the study's cask.[166] Finally, the study occurred only over a fifteen-year period, while the fuel will be active for about a century.[167]

That particular vulnerability was the basis for a recent petition with the United States Court of Appeals for the District of Columbia.[168] In October 2014, ten environmental groups challenged the validity of NRC's "continued storage" rule, which contends that used nuclear fuel from commercial reactors can be safely stored in reactor fuel storage pools in the short-term and in dry casks in the long-term.[169] The groups argued that the rule failed to consider the long-term environmental effects of indefinite storage via dry casks, and thus violated several federal laws, including the AEA.[170] This petition comes two years after a court ruling that the NRC violated the National Environmental Policy Act when it failed to consider the

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160 *Dry Cask Storage*, *supra* note 157.

161 STEWART & STEWART, *supra* note 36, at 265.

162 ALLEY & ALLEY, *supra* note 39, at 118.

163 *Id.* at 119.

164 *Id.*

165 *Id.*

166 *Id.*

167 *Id.* at 120.

168 Hannah Northey, *Green Groups Join States' Fight Against Waste Policy Rule*, E&E REPORTER (Oct. 29, 2014), http://www.eenews.net/eenewspm/2014/10/29/stories/1060008083.

169 *Industry Commends NRC's Final Used Fuel Storage Rule*, NUCLEAR ENERGY INST., http://www.nei.org/News-Media/News/News-Archives/Industry-Commends-NRC-s-Final-Used-Fuel-Storage-Ru (last visited Nov. 23, 2014).

170 Northey, *supra* note 168; *see also* Beyond Nuclear, Inc. v. NRC, No. 14-1216 (D.D.C. filed Oct. 29, 2014).

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possibility that a national waste repository might never be built.[171] The court concluded that the NRC did not have sufficient data about the possibility of leaks or fires in spent fuel pools.[172]

III. FRANCE'S PLAN: REPROCESSING

France has been at the forefront of nuclear technology for more than two decades.[173] Some argue that "[t]he French are making their move at a time when U.S. nuclear policy . . . has been locked in a state of perpetual indecision."[174] Fifty-eight power reactors generate over 80 percent of France's electricity,[175] and 17 percent of that is generated by recycled nuclear fuel.[176]

France's spent nuclear fuel reprocessing program began in Marcoule in 1958.[177] The initial reason for the Marcoule Nuclear Site was to provide plutonium for the French military's nuclear weapons program.[178] Later, the vision to introduce reprocessing in the nuclear fuel cycle sparked the need for civilian separation of plutonium on a large scale.[179] As such, the La Hague plant opened in 1966 and was financed by the military and civilian budgets of the Atomic Energy Commission (Commissariat à l'Énergie Atomique, or CEA).[180] The effort at La Hague eventually gained large support from neighboring European countries, as well as Japan, who signed up for French reprocessing services in the 1970s.[181] Military plutonium separation at Marcoule produced an estimated total of six tons of weapon grade

[171] Northey, *supra* note 168.

[172] *Id.*

[173] Szabo, *supra* note 7, at 241.

[174] Ling, *supra* note 29.

[175] Szabo, *supra* note 7, at 241.

[176] *Nuclear Power in France*, WORLD NUCLEAR ASS'N (last updated July 2016), http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx.

[177] Mycle Scheider & Yves Marignac, *Spent Nuclear Fuel Reprocessing in France*, INT'L PANEL ON FISSILE MATERIALS (Apr. 2008), http://fissilematerials.org/library/rr04.pdf.

[178] *Id.*

[179] *Id.*

[180] *Id.*

[181] *Id.*

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plutonium in its lifetime.[182] The Marcoule plant shut down in 1997; however, civilian reprocessing at La Hague continues.[183]

The plutonium separation plant (UP2) at La Hague was originally designed to reprocess gas graphite reactor (GGR) fuel at a rate of 800 tons per year, and between 1966 and 1987 a total of 4,900 tons of GGR fuel were reprocessed at La Hague.[184] In 1976, the capabilities of UP2 were expanded because of a new installation, UP2-HAO, that could process spent nuclear fuel.[185] La Hague's first years reprocessing with UP2-HAO spent nuclear fuel were rocky.[186] Its throughput, or the amount of fuel the plant is capable of reprocessing, was reduced from 800 to 400 to 250 tons per year. After eleven years, the plant reached its "design throughput" of 400 tons per year.[187] In 1989 a second plant, UP3, began operating at La Hague.[188] UP3's capacity is double UP2's, allowing 800 tons of spent fuel to be reprocessed each year.[189] Germany and Japan, France's main customers, both contracted to have their spent fuel reprocessed with UP3, each paying for a total of 6,685 tons in UP3's first decade of reprocessing.[190]

Germany became France's largest foreign reprocessing customer in 1989 after abandoning its own reprocessing plant, with a share of 54 percent of the total foreign contracts through the end of 2005.[191] However, Germany's nuclear phase-out legislation prohibited the shipment of spent fuel to reprocessing plants after July 2005.[192] However, Germany still purchases electricity generated from France's nuclear plants.[193] Japan also decided to build and operate its own reprocessing plant

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[182] *Id.*

[183] Scheider & Marignac, *supra* note 177.

[184] *Id.*

[185] *Id.* (HAO stands for Haute Activité Oxyde).

[186] *Id.*

[187] *Id.*

[188] *Id.*

[189] *Id.*

[190] Scheider & Marignac, *supra* note 177.

[191] *Id.*

[192] *Id.*

[193] YERGIN, *supra* note 1, at 416.

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in 2006.[194] Consequently, France's two largest foreign reprocessing customer countries are not currently extending their contracts at La Hague.[195]

Regardless, a third reprocessing plant at La Hague, UP2-800, was built in 1994.[196] It officially replaced UP2 on January 1, 2004, partly because it can reprocess more fuel—up to 1,000 tons annually.[197] In 2003, the revised licenses for the La Hague plants limited the throughput for UP2-800 and UP3 to 1,000 tons per year. The 2003 revisions also limited the entire site's throughput at 1,700 tons per year.[198]

France's only recent foreign contract is with Italy.[199] Announced on May 9, 2007, it covers the transport and reprocessing of 235 tons of spent fuel from three of Italy's decommissioned nuclear power plants.[200] After the Chernobyl accident in 1986, Italy shut down its nuclear reactors and passed a referendum in 1987 confirming their abandonment of nuclear power.[201]

A. Adopting France's Reprocessing Plan

Today, the United States is still feeling scorned by India, and one of the main arguments against reprocessing is the potential misuse of the technology for nuclear weapons.[202] In the PUREX process, pure plutonium is separated from the radioactive soup, and this pure plutonium is the type that is primarily used to create nuclear weapons.[203] While weapon proliferation is a legitimate concern, reprocessing in the United States is not going to ignite nuclear weapon proliferation. As demonstrated by the atomic bombs dropped on Hiroshima and Nagasaki, the United States already knows how to create a nuclear weapon without reprocessing. The argument that reviving reprocessing in the United States will be misused to create nuclear weapons, therefore, is invalid. Developed and underdeveloped countries alike have the knowledge, technology, and training to make nuclear weapons. If these countries

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[194] Scheider & Marignac, *supra* note 176.

[195] *Id.*

[196] *History*, AREVA, http://www.areva.com/EN/operations-1183/key-dates-for-areva-s-la-hague-site.html (last visited Nov. 21, 2014).

[197] Scheider & Marignac, *supra* note 177.

[198] *Id.*

[199] *Id.*

[200] *Id.*

[201] *Id.*

[202] A. David Rossin, *U.S. Policy on Spent Fuel Reprocessing: The Issues*, PBS, http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/rossin.html (last visited Sept. 26, 2016).

[203] *Id.*

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want to make a nuclear weapon, nothing is stopping them. Thus, reprocessing is not going to further or facilitate a desire to create weapons.

In a post-9/11 world, terrorism is a concern. Skeptics argue that if separated plutonium was shipped in commerce for reprocessing, terrorists could steal it and make a bomb.[204] However, terrorists are not likely to make the plutonium into a bomb because once they would open the vessel containing the plutonium, they would be hit with harmful radiation.[205] A more likely scenario for terrorists would be threatening to release the radioactive powder into the air.[206] "The actual threat to health would be very low, but the likelihood of panic would be very high indeed."[207] However, nuclear weapon components have been routinely shipped throughout the United States in unmarked trucks for decades.[208] Shipments of plutonium oxide in Europe are carefully accounted for, packaged and sealed, and transported under very stringent security.[209] Despite outcries from several Asian nations, Japan has sent spent fuel to France for reprocessing.[210] The ship that carried the spent fuel was safeguarded and monitored under tight international controls and was transported without issue.[211] Even domestically, substantial shipments of government and commercial spent nuclear fuel ship under strict regulation and without incident.[212] For example, damaged fuel at Three Mile Island was transferred to the Idaho National Laboratory.[213] Additionally, roughly sixty casks were transported annually between the United States and foreign researchers as a part of the Atoms of Peace Initiative in the 1950s.[214] Only nine accidents involving shipments have happened between 1971 and 2003, and none released radiation or were a result of terrorism.[215]

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[204] Rossin, *supra* note 202.

[205] *Id.*

[206] *Id.*

[207] *Id.*

[208] *Id.*

[209] *Id.*

[210] *Id.*

[211] *Id.*

[212] STEWART & STEWART, *supra* note 36, at 133.

[213] *Id.*

[214] *Id.*

[215] *Id.* at 134; *see also* COMMITTEE ON TRANSPORTATION OF RADIOACTIVE WASTE, GOING THE DISTANCE?: THE SAFE TRANSPORT OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE IN THE UNITED STATES 123 (2006) (The chart shows that there were nine total incidents, four involving trucks and five involving trains. The accidents were mainly due to the truck or train failure, like a wheel failure or derailment. None were a result of terrorism.).

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Education about the low risk of a terrorist attack involving spent nuclear fuel in transit could reassure the public about implementing a reprocessing program.

Cost is another argument against reprocessing. Uranium is cheap fuel now, but critics estimate that reprocessing will cause the price of uranium to skyrocket.[216] This argument is unsound. Recycling the uranium in a closed fuel cycle will create a lesser demand for it, and thus, there will be more supply. Theoretically, reprocessing can extend the world's uranium resources "'almost indefinitely.'"[217] With more of a uranium supply and less demand, the cost of uranium is bound to decrease, not increase. Even if the price of uranium decreases, opponents point to the failed attempts to competitively price MOX fuel against enriched uranium.[218] On average, power produced from MOX fuel costs two cents more than that produced from uranium fuel, which is tenfold higher than the underlying resource cost.[219] The PUREX process is also expensive.[220] France spends 800 million euros, or about 1.1 billion U.S. dollars, more per year for reprocessed fuel than they would for conventional uranium fuel rods.[221] In 1996, the National Research Council estimated that reprocessing spent nuclear fuel in the United States would cost at least 100 billion dollars.[222] Consequently, some form of government assistance, such as what was proposed for the GNEP, may be necessary to make reprocessing viable.[223] Government involvement could also make the public feel more secure about reprocessing nuclear waste.

Additionally, the United States' hiatus on reprocessing gives the nation a better opportunity to make the process more economically efficient and technologically

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[216] Richard Harris, *Nuclear Waste May Get a Second Life*, NAT'L PUB. RADIO (Apr. 9, 2010, 12:00 AM), http://www.npr.org/templates/story/story.php?storyId=125740818.

[217] Emily Casey, Comment, *Waist-Deep in Nuclear Waste: How the NRC Can Rebuild Confidence in a Stalled Waste Management Program*, 33 J. NAT'L ASS'N ADMIN. L. JUDICIARY 723, 764 (2013) (quoting Richard Rhodes & Denis Beller, *The Need for Nuclear Power*, 79 FOREIGN AFFAIRS 30, 41 (2000)).

[218] David Biello, *Is Reprocessing the Answer to Eliminating Fissile Materials from Bombs and Nuclear Waste?*, SCI. AM. (Apr. 15, 2010), http://www.scientificamerican.com/article/is-reprocessing-the-answer-to-eliminating-fissile-materials/.

[219] Biello, *supra* note 218.

[220] *Id.*

[221] *Id.*

[222] *Id.*

[223] Max S. Power, *Reprocessing Nuclear Fuel Makes Sense, But Is It Sensible?*, PAC. STANDARD (May 20, 2009), https://psmag.com/reprocessing-nuclear-fuel-makes-sense-but-is-it-sensible-a72d67ad7a63#.2xm4e4gwx.

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advanced.[224] The United States can analyze what France spends on reprocessed fuel and try to remedy the problem before implementing it in practice. Therefore, the United States can look to France generally for implementing a reprocessing system while also learning from France's mistakes.

Advocates for the revival of reprocessing in the United States primarily point to environmental benefits over cost.[225] In effect, advocates contend that reprocessing will provide a "plentiful, secure, long-term source of fuel for low-carbon nuclear power while significantly reducing the volume of, and formidable technical and political challenges posed by, nuclear wastes requiring repository disposal."[226] Only about three percent of the world's radioactive waste can be reprocessed.[227] If it were, then that three percent would be reduced by one-fifth.[228] Therefore, the actual high-level waste would be reduced, but not significantly. However, the storage vessels needed for waste that has been reprocessed are far more space efficient compared to the vessels needed for spent fuel that has not been reprocessed.[229] The open fuel cycle buries the entire fuel assembly, while the closed fuel cycle transforms the waste into glass.[230] Although waste is only slightly reduced, the storage for the reprocessed fuel saves a significant space in repositories.

Not only does reprocessing address the volume problem, it also breaks plutonium into shorter-lived isotopes with less explosive properties than regular spent nuclear fuel, significantly reducing the radioactivity of nuclear waste over time.[231] Even more, disposal of reprocessed waste through vitrification is more durable than the current methods of storage.[232]

If the reprocessing program is eventually revived in the United States, public perception will be a large hurdle. However, overcoming that hurdle could be as

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[224] *Id.* (arguing that the hiatus in American reprocessing is a benefit because the country is not saddled with "dated recycling infrastructure").

[225] STEWART & STEWART, *supra* note 36, at 46.

[226] *Id.*

[227] Only high-level radioactive waste can be reprocessed. *See Waste Management Overview*, *supra* note 53.

[228] *Id.*

[229] *Id.*

[230] *Id.*

[231] Casey, *supra* note 217, at 764.

[232] Biello, *supra* note 218 (statement of Alan Hanson, Executive Vice President of Technologies and Used-Fuel Management at AREVA, a French nuclear power company that conducts that country's reprocessing) ("Used fuel is hotter than hell. And nobody designed it to be thrown away. Glass has durability.").

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simple as a marketing tactic. By advertising a reprocessing program as a "recycling" program, the public is probably more likely to jump on board since recycling is generally regarded positively. In a nation that recycles plastic bottles, aluminum cans, and paper, why not recycle nuclear waste? Thus, by marketing reprocessing as recycling, the public is likely to view it in a positive light.

A name change alone is likely to be insufficient for public reception. The technology is present, but political support is needed, and that requires incentives for it to be profitable. In France, the reprocessing program has strong political support, and a similar movement in the United States would likely require the same support. It would be the responsibility of the nuclear energy industry to educate the government and the public about nuclear fuel reprocessing, and it would be up to the public to change dated perceptions of the nuclear energy industry.

Revitalizing the reprocessing program also could create domestic jobs. In France, 6,000 people work on the 750-acre La Hague site today.[233] The United States is more than eighteen times the size of France[234] and has almost double the nuclear reactors.[235] If the United States sets up reprocessing facilities, it may create two times more jobs than reprocessing does in France.

CONCLUSION

Implementing a reprocessing system in the United States is crucial to reduce overall environmental impact of nuclear energy production. Terrorism, cost, and illegitimatized fears are the only factors halting the progress of what could be a major environmental triumph. Reprocessing technology can unlock the useful energy in the nation's enormous stockpile of spent nuclear fuel, and could eventually solve the waste repository problem.[236] Additionally, a reprocessing program could create domestic jobs. While the monetary cost of reprocessing is significant, it is not greater than the cost on the environment if the United States' open fuel cycle continues. In order to be successful, there must be a push to educate the public about current nuclear waste management compared to how it can be improved through reprocessing. Advocates for reprocessing could market their campaign as a recycling program in order to emphasize its safety and environmental benefits. The government must also step in to finance a reprocessing program and settle the unease the public associates with nuclear power generation.

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[233] Scheider & Marignac, *supra* note 177.

[234] *Square Miles: Countries Compared*, NATION MASTER, http://www.nationmaster.com/ country-info/stats/Geography/Land-area/Square-miles (last visited Nov. 30, 2014).

[235] *See Nuclear Power in France*, *supra* note 176; *How many nuclear power plants*, *supra* note 16.

[236] STEWART & STEWART, *supra* note 36, at 46.

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The United States should revive "Plan A" for reprocessing nuclear fuel, modeled after the process France uses. Fear of nuclear proliferation and economic costs of reprocessing are small concerns compared to the large environmental impact nuclear waste can have in the long term.

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