ARTICLE

AN UNATTAINABLE WEDGE: FOUR LIMITING EFFECTS ON THE EXPANSION OF NUCLEAR POWER

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As international efforts continue to move toward a cap and trade system for greenhouse gases ("GHGs"), it remains to be seen what role the United States may play in such efforts. Traditionally, the United States has taken a soft approach to international climate change by choosing to ratify only voluntary or nonbinding efforts.[1] A soft international stance, however, does not mean that the United States will take a soft domestic approach. Indeed, a U.S. cap and trade system may be forthcoming.[2]

President Barack Obama's pre-election campaign stressed the importance of instituting a cap and trade system and promised to reduce GHG emissions to eighty percent of 1990 levels by 2050.[3] Since 1990, GHG emissions in the United States have increased by about 17.1%.[4] In furtherance of that promise, an attempt was made to attach a cap and trade system to the

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1. U.S. opposition to binding international treaties can be seen in the Kyoto Protocol. After the United States became a signatory to the Kyoto Protocol, the Byrd-Hagel Resolution unanimously passed by the U.S. Senate advised the Clinton Administration not to accept binding obligations under the Kyoto Protocol unless developing countries did the same. As a result, the Kyoto Protocol was never ratified. *See* S. REP. NO. 105–54, at 3 (1997); Lisa Friedman, *Climate Talks in Copenhagen—Milepost or Turning Point*, N.Y. TIMES, Dec. 7, 2009, *available at* http://www.nytimes.com/cwire/2009/12/07/07climatewire-climate-talks-in-copenhagen----milepost-or-t-72987.html. The United States, however, did agree to the Asia Pacific Partnership on Clean Development and Climate Change on January 12, 2006 which was a non-binding effort to advance climate change initiatives. *See* Bureau of Pub. Affairs, U.S. Dep't of State, U.S. Government Website for the Asia-Pacific Partnership on Clean Development and Climate, http://www.app.gov/about/key/index.htm (last visited Mar. 19, 2010).

2. John M. Broder, *Curtain Rises Today on Senate Struggle Over Climate Change Legislation*, N.Y. TIMES, Sept. 30, 2009, at A19, *available at* 2009 WLNR 19236080.

3. Michael B. Gerrard, *McCain vs. Obama on Environment, Energy, and Resources*, NAT. RESOURCES & ENV'T, Fall 2008, at 3–4.

4. U.S. ENVTL. PROT. AGENCY, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2007 ES-4 (2009).

2009 budget reconciliation process and failed.[5] Still, the Omnibus Spending Bill, signed into law on March 11, 2009, required the Environmental Protection Agency ("EPA") to finalize a proposed rule to require industries to file an annual report on GHG emissions by June 26, 2009.[6] Just a few weeks later, the EPA issued the long awaited "endangerment finding" for GHG emissions.[7] An endangerment finding is a necessary precursor that triggers the EPA's nondiscretionary duty to regulate harmful pollutants under the Clean Air Act ("CAA").[8] Such a finding is likely to trigger a "cascade of permitting requirements" on carbon emissions in the very near future.[9] As a result, the electric industry is preparing for the inevitable establishment of a carbon allowance and trade system by examining the feasibility of carbon-reducing technologies and alternatives.[10] Nuclear power is at the top of the list for many.

Forty-three new reactors representing 37,668 megawatts electrical (MWe) are currently under construction around the world, and another 374 have been ordered or proposed.[11] Although the United States has been somewhat more reluctant than the rest of the world to expand its existing stock of nuclear power plants, these sentiments may be changing.[12] The Nuclear Regulatory Commission ("NRC") has already received applications for twenty-eight nuclear power reactors since 2007.[13] Not all of these plants will ultimately be built (even if the NRC

5. Kyle Danish et al., *Weekly Climate Change Policy Update*, MONDAQ, March 17, 2009, *available at* 2009 WLNR 5058143.

6. Rep. Steve King, *Rep. King Secures $282,000 for Hungry Canyons Alliance*, U.S. FED. NEWS, Mar. 27, 2009, *available at* 2009 WLNR 5765624; Danish, *supra* note 5; *See generally* Mandatory Reporting of Greenhouse Gases, 74 Fed. Reg. 16,448 (proposed Apr. 10, 2009) (to be codified at 40 C.F.R. pt. 86, 87, 89, et al.).

7. Tom LoBianco, *New Action on Medicine, Environment; Carbon Dioxide Classified Pollutant*, WASH. TIMES, Apr. 18, 2009, at A01.

8. Clean Air Act § 108, 42 U.S.C. § 7408 (1998).

9. Danish, *supra* note 5.

10. *See* Gulf Coast Power Ass'n, Follow the Money: Investing in the Future of the Texas Electric Markets (Apr. 2–3, 2009) (unpublished brochure, on file with the Environmental & Energy Law & Policy Journal), *available at* http://www.gulfcoastpower.org/default/s09brochure.pdf.

11. World Nuclear Ass'n, World Nuclear Power Reactors 2007–09 and Uranium Requirements (Feb. 5, 2009), http://www.world-nuclear.org/info/reactors-Feb2009.htm.

12. *See* INT'L ATOMIC ENERGY AGENCY, INTERNATIONAL STATUS AND PROSPECTS OF NUCLEAR POWER 2 (2008) (stating that of 30 countries currently using nuclear power, 24 intend to allow new plants to be build and the majority are providing incentives for that purpose); ENERGY INFO. ADMIN., INTERNATIONAL ENERGY OUTLOOK 2008, at 65 (2008) [hereinafter EIA, INTERNATIONAL ENERGY OUTLOOK 2008].

13. U.S. Nuclear Regulatory Comm'n, Combined License Applications for New Reactors (Jan. 4, 2010), http://www.nrc.gov/reactors/new-reactors/col.html.

approves the applications), but at least six applicants already have financial backing for construction.[14]

Using nuclear power as a wedge to reduce primary baseload carbon emissions may prove to be an unattainable goal. This paper examines the feasibility of using nuclear power as a wedge to reduce CO_2 emissions and puts forth four factors that may prevent or inhibit the growth of the nuclear power industry: (1) antinuclear cultural perception, (2) the failure of nuclear waste policy, (3) the effect of volatile prices, and (4) the effect of Smart-Grid technology.

I. AN INTRODUCTION TO CAP AND TRADE AND THE NUCLEAR WEDGE DEBATE

In 2000, Princeton University received a twenty million dollar grant to study and develop a solution to the GHG problem.[15] The grant consisted of a fifteen million dollar pledge by BP and a five million dollar pledge by Ford Motor Company.[16] Four years later, Robert Socolow and Stephen Pacala of Princeton University released an outreach model known as the stabilization triangle in which existing technologies could be used to stabilize carbon dioxide emissions for the next fifty years.[17] The model spurred a scholarly debate concerning the best way to tackle an extremely large carbon dioxide emission problem.[18]

According to the Socolow-Pacala model, the ocean and land biosphere act as a filter removing carbon dioxide from the air at a rate of four billion tons per year.[19] Meanwhile, fossil fuel combustion adds about eight billion tons yearly.[20] Currently, the earth's atmosphere contains a little more than 800 billion tons of carbon dioxide, but the amount is steadily climbing.[21] Unless significant changes are made, the yearly contribution to the total carbon content of the atmosphere is expected to "double its pre-

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14. *See* Advocate Business Staff, *Shaw, Westinghouse Sign Nuke Deal*, THE ADVOCATE, Jan. 5, 2009, http://www.2theadvocate.com/news/business/37097629.html.

15. Press Release, Princeton University, Princeton Receives $20 Million Grant to Address Greenhouse Problem (Oct. 25, 2000), *available at* http://www.princeton.edu/pr/news/00/q4/1025-greenhouse.htm.

16. *Id.*

17. PRINCETON ENVTL. INST., CARBON MITIGATION INITIATIVE, FOURTH YEAR REPORT 26 (2005); Press Release, Princeton University, Technology Already Exists to Stabilize Global Warming (Aug. 12, 2004), *available at* http://www.princeton.edu/pr/news/04/q3/0812-carbon.htm.

18. *See id.*

19. ROBERTA HOTINSKI, PRINCETON ENVTL. INST., STABILIZATION WEDGES: A CONCEPT & GAME 2 (2007), *available at* http://cmi.princeton.edu/wedges/pdfs/teachers_guide.pdf.

20. *Id.*

21. *Id.*

industrial value".[22] Socolow and Pacala surmised that if carbon emissions were sustained at the current level (by eliminating eight billion tons of carbon output) for the next fifty years, the doubling of CO_2 would be avoided.[23] As a solution, the Princeton professors divided the eight-billion-ton emission triangle into eight smaller wedges of one billion tons each.[24] As the carbon wedge model gained popularity, the Natural Resources Defense Council computed the size of one "U.S. wedge" to be one gigaton carbon dioxide equivalent (Gt CO_2 eq.), or 175 gigawatts electrical (GWe).[25] The Socolow-Pacala model presents fifteen different strategies in four categories that could lower carbon dioxide emissions.[26] The four categories are: efficiency and conservation, strategies to reduce emissions from fossil fuels, nuclear energy, and the use of renewable energy and bio-storage technologies.[27] This article focuses primarily on the use of nuclear power for electricity.

A. The Nuclear Wedge: Problem or Solution?

By 2020, the extended licenses of eighteen U.S. nuclear power plants will expire.[28] Simultaneously, the Energy Information Administration ("EIA") expects the demand for electricity to increase even though per capita energy use may decline.[29] Assuming that all expiring nuclear reactors are replaced, by 2030 electric prices could grow 10.4-10.8 cents per KWh (almost double the current national average).[30] The imposition of a carbon trading system (hereinafter referred to simply as a carbon tax), however, will further increase electric prices in proportion to the electric fuel's carbon emissions.[31] Although it is perhaps impossible to determine exactly how much the price of electricity would increase under a free market carbon trading system, a carbon tax of $100 per ton[32] would raise electric

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22. *Id.*
23. Stephen Pacala & Robert Socolow, *Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies*, SCIENCE, Aug. 13, 2004, at 968.
24. HOTINSKI, *supra* note 19, at 3.
25. Thomas B. Cochran, Nuclear Program Dir., Natural Res. Def. Council, Environmental, Safety, and Economic Implications of Nuclear Power, Statement Before the California Energy Commission of Sacramento, (June 28, 2007), at 14.
26. HOTINSKI, *supra* note 19, at 3.
27. *Id.*
28. U.S. NUCLEAR REGULATORY COMM'N, 2008-2009 INFORMATION DIGEST 48 (2008) [hereinafter U.S. NRC, INFO. DIGEST].
29. *See* ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2009: WITH PROJECTIONS TO 2030 61, 71 (2009).
30. *See id.* at 73.
31. *See id.* at 3.
32. $100 per ton is a relatively high carbon price estimate. *See id.* at 29 ("Typically, the emissions prices used have ranged from $5 to $80 per metric ton."). *Contra* CONG.

prices 13-36% (1.4-1.7 cents per KWh),[33] and increase the general price of goods approximately 2.8%.[34]

If no new nuclear power plants are built, the entire fleet of U.S. nuclear reactors will expire, enlarging the climate problem by sixteen percent of a global wedge or sixty-four percent of a U.S. wedge.[35] Supposing instead that the existing U.S. fleet is expanded by the twenty-eight proposed power plants, the new plants would add an extra forty GWe of electrical generating capacity to the United States and reduce emissions by about 22.8% of one U.S. carbon wedge.[36] Thus, proponents of nuclear energy have advocated the use of nuclear power as a strategy to reduce carbon emissions. Even if nuclear energy becomes economically feasible, there are other problems that might prevent or inhibit the resurgence of nuclear use.

II. MODERN ENERGY USAGE

World energy consumption is growing at a rate of 3.2% per year.[37] In 2005, the world consumed 462 quadrillion BTUs ("quads") of energy.[38] One quad is approximately equal to 293 billion kilowatt hours of energy.[39] Thirty-five percent of that consumption was supplied by liquid hydrocarbons. The rest was supplied by: coal, 25.3%; natural gas, 20.7%; nuclear, 6.3%; hydro-power, 2.2%; combustible renewable fuels, 10%; and other

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BUDGET OFFICE, WHO GAINS AND WHO PAYS UNDER CARBON ALLOWANCE TRADING? THE DISTRIBUTIONAL EFFECTS OF ALTERNATIVE POLICY DESIGNS 9 (2000) [hereinafter CBO, WHO GAINS AND WHO PAYS] ("Based on empirical studies of the extent to which carbon emissions would decrease as the price of emitting carbon increased, the Congressional Budget Office (CBO) estimates that a fifteen percent cut in emissions would correspond to an allowance price of $100").

33. *See* CBO, WHO GAINS AND WHO PAYS, *supra* note 32, at 9; Mark Lasky, *The Economic Costs of Reducing Emissions of Greenhouse Gases: A Survey of Economic Models* 30 (Cong. Budget Office, Technical Paper Series 2003–3, 2003).

34. CBO, WHO GAINS AND WHO PAYS, *supra* note 32, at 9; *See generally* PEW CTR. ON GLOBAL CLIMATE CHANGE, CONTAINING THE COSTS OF CLIMATE POLICY (2008), *available at* http://www.pewclimate.org/docUploads/DDCF-Costs.pdf (explaining that a more detailed analysis on how carbon trading could affect prices and household income); *see also* DALE W. JORGENSON ET AL., PEW CTR. ON GLOBAL CLIMATE CHANGE, THE ECONOMIC COSTS OF A MARKET-BASED CLIMATE POLICY (2008), *available at* http://www.pewclimate.org/docUploads/economic-costs-market-based-climate-policy-june2008.pdf.

35. *See* HOTINSKI, *supra* note 19, at 6 (stating that that phasing out all world nuclear power plants would add 1/2 of a wedge to world emissions); U.S. NRC, INFO. DIGEST, *supra* note 28, at 26 (stating the U.S. nuclear fleet makes up 32% of world nuclear capacity).

36. *See* CONG. BUDGET OFFICE, NUCLEAR POWER'S ROLE IN GENERATING ELECTRICITY 9 (2008) [hereinafter CBO, NUCLEAR POWER'S ROLE].

37. *See* EIA, INTERNATIONAL ENERGY OUTLOOK 2008, *supra* note 12, Ch. 1.

38. *Id.* at 7.

39. *See* American Physics Society, Policy and Advocacy, Energy Units, http://www.aps.org/policy/reports/popa-reports/energy/units.cfm (last visited Mar. 19, 2010).

sources, 0.5%.[40] By 2030, however, the world may consume as much as 695 quads of energy per year.[41] In 2007, the United States alone consumed approximately one-fifth of world demand or 101.6 quadrillion BTUs of energy.[42] By 2030, U.S. energy demand is expected to account for seventeen percent of total world consumption.[43] Most of this consumption, about forty percent, goes to electric power generation.[44]

A. Traditional Baseload Power Fuels

Electric generation world-wide has relied primarily on fossil fuels since its inception.[45] Fossil fuel combustion, however, produces harmful GHGs such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and sulfur dioxide (SO_2).[46] These GHGs contribute to extreme weather patterns such as arctic ice sheet melting, drought, heavy precipitation, heat waves, and intense tropical cyclones.[47]

Low fuel, capital costs, and the abundance of local fuel sources make coal the most popular electric fuel in the United States.[48] Forty-nine percent of electric generation in the United States relies on coal.[49] Coal is the dirtiest fossil fuel and emits 2,249 pounds of CO_2, thirteen pounds of SO_2, and six pounds of N_2O per million watt-hours (MWh) of electricity produced.[50] Other by-products of coal combustion include "fly ash, fluidized bed combustion residues, flu gas, desulfurization sludge, and bottom ash."[51] As a result, coal power plants are responsible for eighty-three percent of electricity related GHG emissions in the United States.[52]

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40. INT'L ENERGY AGENCY, KEY WORLD ENERGY STATISTICS 2007 6 (2007).

41. *See* EIA, INTERNATIONAL ENERGY OUTLOOK 2008, *supra* note 12, at 7.

42. *See* ENERGY INFO. ADMIN., ANNUAL ENERGY REVIEW 2008 9, tbl. 1.3 (2009) [hereinafter EIA, ANNUAL ENERGY REVIEW 2008].

43. EIA, INTERNATIONAL ENERGY OUTLOOK 2008, *supra* note 12, at 7.

44. EIA, ANNUAL ENERGY REVIEW 2008, *supra* note 42, at 38, fig.2.1a.

45. *See id.* at xx.

46. U.S. ENVTL. PROT. AGENCY, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2007 ES-17-19 (2009).

47. RICHARD B. ALLEY ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SUMMARY FOR POLICYMAKERS: A REPORT OF WORKING GROUP I OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 7 (2007).

48. *See* CBO, NUCLEAR POWER'S ROLE, *supra* note 36, at 25.

49. EIA, ANNUAL ENERGY REVIEW 2008, *supra* note 42, at 228, fig.8.2a.

50. Ross Wingo & H. Sterling Burnett, *Nuclear Renaissance: Atoms to Power the Future*, NAT'L CENTER FOR POL'Y ANALYSIS, Oct. 21, 2008, http://www.ncpa.org/pdfs/ba635.pdf; CBO, NUCLEAR POWER'S ROLE, *supra* note 36, at 21.

51. Office of Surface Mining, Dep't of Interior, CCB Information Network: Coal Combustion By-Products, http://www.mcrcc.osmre.gov/ccb/ (last visited Mar. 19, 2010).

52. ENERGY INFO. ADMIN., GREENHOUSE GASES, CLIMATE CHANGE & ENERGY (2008), *available at* http://www.eia.doe.gov/bookshelf/brochures/greenhouse/Chapter1.htm.

Natural gas, on the other hand, is the cleanest burning fossil fuel and generates twenty-one percent of electricity in the United States.[53] Natural gas emits 1,135 pounds of CO_2, 0.1 pounds of SO_2, and 1.7 pounds of N_2O per MWh.[54] In total, natural gas is responsible for fifteen percent of GHG emissions from electrical generation in the United States.[55] Despite the cleaner burning nature of natural gas, gas plants are rarely used for baseload power generation, mostly because gas is extremely price volatile.[56] Prices can change by as much as 200% in a short time frame.[57] Instead, the low capital costs of natural gas plants make them attractive for use as peak cycling facilities.[58]

Petroleum is rarely used for baseload electric generation because of high fuel costs and the potential for supply interruption.[59] Generating plants that use petroleum emit twelve pounds of SO_2 and four pounds of N_2O per MWh.[60] Petroleum power plants have steadily declined in the Unites States since the oil embargo of 1973.[61] Today less than three percent of electric generation comes from petroleum.[62]

B. Nontraditional Baseload Power Fuels

Nuclear power does not generate GHGs, but it does create hazardous radioactive wastes that must be disposed of somewhere.[63] A spent nuclear fuel rod is ninety-six percent uranium and four percent other isotopes created by fission.[64] These fission by-products have half-lives longer than a million years.[65] For instance, iodine-129 has a half-life of seventeen million years, and plutonium-239 has a half-life of 24,360 years.[66]

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53. EIA, ANNUAL ENERGY REVIEW 2008, *supra* note 42, at 228, fig.8.2a.
54. Wingo & Burnett, *supra* note 50.
55. *See* U.S. Envtl. Prot. Agency, 2010 Draft U.S. Greenhouse Gas Inventory Report 5, http://www.epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010-Chapter-Energy.pdf (last visited Mar. 19, 2010).
56. CBO, NUCLEAR POWER'S ROLE, *supra* note 36, at 20.
57. *Id.* at 19.
58. *Id.* at 2.
59. Energy Info. Admin., Overview—Electric Power Industry—Chapter 3, http://www.eia.doe.gov/cneaf/electricity/page/prim2/chapter3.html#fossil (last visited Mar. 19, 2010) [hereinafter EIA, Electricity Generation].
60. Wingo & Burnett, *supra* note 50.
61. EIA, Electricity Generation, *supra* note 59.
62. *Id.*
63. *Nuclear Rising on Both Sides of the Atlantic*, EUR. AFF., Fall/Winter 2006, at 42, 42–54, http://www.worldnuclear.org/John_Ritch_speeches/John_Ritch_euro_affairs-0207.html.
64. Karl S. Coplan, *The Intercivilizational Inequities of Nuclear Power Weighed Against the Intergenerational Inequities of Carbon Based Energy*, 17 FORDHAM ENVTL. L. REV. 227, 234 (2006).
65. *Id.*
66. *Id.*

In addition to the isotopes produced by fission, the decommissioning of nuclear plants produce a significant amount of waste caused by the steel's prolonged exposure to radioactive materials such as iron-55, cobalt-60, nickel-63, and carbon-14.[67] Today, nuclear power accounts for twenty percent of U.S. electric generating capacity.[68] These nuclear plants are highly efficient and have extremely long operating lives compared to other types of power plants.[69] High capital costs, however, have inhibited the attractiveness of nuclear technology for the past thirty years.[70]

Hydroelectric power is a cheap renewable source of energy that produces few GHGs and little thermal pollution.[71] Some of the limitations of hydroelectric power include environmental damage to riparian[72] habitats, water pollution, navigable waterway passage restriction, high capital costs, displacement of human populations, and large land and water flow requirements.[73] Hydroelectric power produces twenty percent of electricity world-wide, but in the United States, only about six percent of electric capacity comes from hydroelectric power.[74] Other various energy technologies supply about five percent of U.S. electrical production.[75]

C. Modern Technologies

The American Recovery and Reinvestment Act of 2009 provided $3.4 billion for carbon capture research and planning.[76] Carbon dioxide capture and storage ("CCS") is a new process that "separate[s] CO_2 from . . . energy-related sources [and] transport[s it] to a storage location [for] long-term isolation" from

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67. *See* WORLD NUCLEAR ASS'N, RADIOACTIVE WASTE MANAGEMENT (2009), http://www.world-nuclear.org/info/inf04.htm.

68. EIA, ANNUAL ENERGY REVIEW 2008, *supra* note 42, at 228, fig. 8.2a.

69. *See* LARRY PARKER & MARK HOLT, CONG. RESEARCH SERV., NUCLEAR POWER: OUTLOOK FOR NEW U.S. REACTORS 5 (2007), *available at* http://www.fas.org/sgp/crs/misc/RL33442.pdf.

70. CBO, NUCLEAR POWER'S ROLE, *supra* note 36, at 20.

71. EIA, Electricity Generation, *supra* note 59.

72. Riparian means of or along the banks of a natural water course. Plant communities along a river's margin are called riparian vegetation. Riparian areas impact soil conservation, biodiversity, and aquatic ecosystems. *See* Stephanie Parkyn, No: 1171-4662, *Rev. of Riparian Buffer Zone Effectiveness*, MAF TECHNICAL PAPER NO: 2004/05, 7 (N.Z. Ministry of Agric. and Forestry, September 2004) (available at http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/resource-management/review-riparian-buffer-zone-effectiveness/techpaper-04-05-riparian-effectiveness.pdf).

73. U.S. GEOLOGICAL SURVEY, HYDROELECTRIC POWER WATER USE (2009), http://ga.water.usgs.gov/edu/wuhy.html.

74. *Id.*

75. EIA, ANNUAL ENERGY REVIEW 2008, *supra* note 42, at 228, fig. 8.2a.

76. Am. Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, Title IV (2009).

the environment.[77] Large point sources emit nearly thirteen gigatons of CO_2 per year.[78] The captured CO_2 can then be stored in geological formations such as empty natural gas reservoirs or converted to mineral carbonates for use in industrial processes–although industrial conversion is not expected to significantly contribute to CO_2 abatement.[79] The Intergovernmental Panel on Climate Change ("IPCC") estimates that there are roughly 1,100 gigatons of underground storage space worldwide.[80] All of the component parts of a potential CCS system exist, but implementation is still waiting for the right economic conditions.[81] CCS technology would increase the cost of electricity by as much as 1.6 to 8.3 cents per kWh.[82] The implementation of CCS technology would also increase the amount of fuel needed for electrical generation.[83]

The U.S. Energy Policy Act of 2005 and the Advanced Energy Initiative of 2006 encourage the construction of advanced nuclear reactors by offering incentives for construction, fast-track licensing, research and design funding, and liability protection.[84] There are two types of advanced reactors: Generation III+ and Generation IV.[85] Generation III+ reactors are ready for commercial operation and include the Westinghouse AP1000,[86] Areva EPR,[87] GE ESBWR,[88] and CANDU ACR1000.[89] These reactors are modular, which enable them to be built in less than

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77. JUAN CARLOS ABANADES ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CARBON DIOXIDE CAPTURE AND STORAGE: SUMMARY FOR POLICYMAKERS 3 (2005).

78. U.S. Envtl. Prot. Agency, Climate Change—Greenhouse Gas Emissions: Geologic Sequestration, http://www.epa.gov/climatechange/emissions/co2_geosequest.html (last visited Mar. 19, 2010) [hereinafter EPA, Geologic Sequestration].

79. ABANADES ET AL., *supra* note 77, at 3.

80. EPA, Geologic Sequestration *supra* note 78.

81. ABANADES ET AL., *supra* note 77, at 12.

82. *Id.* at 10.

83. *Id.* at 4.

84. Jonathan Koomey and Nathan E. Hultman, *A Reactor-Level Analysis of Busbar Costs for US Nuclear Plants (1970–2005)*, 35 ENERGY POL'Y 5630, 5631 (Elsevier, 2007).

85. *Id.*

86. The Westinghouse AP1000 is a U.S. designed "advanced pressurized reactor." Westinghouse, AP1000 at a Glance, http://www.ap1000.westinghousenuclear.com/ap1000_glance.html (last visited Mar. 19, 2010).

87. The Areva EPR is a European designed "pressurized reactor." *See* Areva, EPR: The First Generation III+ Reactor Currently under Construction, http://www.arevanp.com/scripts/info/publigen/contect/templates/show.asp?L=US&P=1655&SYNC=Y (last visited Mar. 19, 2010).

88. General Electric's ESBWR stands for "economic simplified boiling water reactor." *See* GE Hitachi, Nuclear Energy, ESBWR Fact Sheet (2008), http://www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors/esbwr.htm.

89. The CANDU ACR 1000 is a Canadian designed advanced heavy water reactor. CANDU stands for "Canadian Deuterium Uranium." ACR stands for "Advanced CANDU Reactor." *See* Atomic Energy of Canda Limited, CANDU Reactors, Canadian Technology, http://www.aecl.ca/Reactors.htm (last visited Mar. 19, 2010).

four years.[90] They also incorporate passive safety features such as using gravity to cool the reactors rather than an external pumping system which eliminates the risk of leaks caused by the degradation of pressurized pipes.[91]

Generation IV reactors are a product of international cooperative design efforts. In July 2001, the U.S. Department of Energy ("DOE") convened the first meeting of the Generation IV International Forum ("GIF"), a panel consisting of nuclear technology experts from nine countries, to discuss the development of new nuclear technology.[92] Today GIF members include Argentina, Brazil, Canada, China, France, Japan, Republic of Korea, the Russian Federation, Republic of South Africa, Switzerland, the United Kingdom, the United States, and the European Union's Atomic Energy Commission ("Euratom").[93] GIF designed six different categories of next generation advanced nuclear technology which feature increased modularity, proliferation resistance, and alternative fuel cycles.[94] These reactors are expected to be construction-ready in fifteen to twenty years.[95]

III. LEGISLATIVE BACKGROUND

A. Atomic Energy Act of 1946

Fear of nuclear energy's dangerous potential drove decisions about nuclear energy from the very inception of the technology. Shortly after Columbia University's first successful fission experiment in the United States, Albert Einstein and Leo Szilard wrote a letter to President Roosevelt warning him of the potential danger of allowing Germany to be the first country to develop a nuclear weapon.[96] Although the letter was initially overlooked, one month later Hitler invaded Poland, thus starting

90. Koomey & Hultman, *supra* note 84, at 5631.
91. GE Hitachi, Nuclear Energy, Advanced Boiling Water Reactor (ABWR) Fact Sheet (2008), http://www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors/abwr.htm; Koomey & Hultman, *supra* note 84, at 5630.
92. Generation IV International Forum (GIF), Origins of the GIF, http://www.gen-4.org/GIF/About/origins.htm (last visited Mar. 19, 2010).
93. *Id.*
94. Generation IV International Forum (GIF), Generation IV Systems, http://www.gen-4.org/Technology/systems/index.htm (last visited Mar. 19, 2010).
95. Koomey & Hultman, *supra* note 84, at 5630.
96. Letter from Albert Einstein (with Leo Szilard), to President Franklin Roosevelt, (Aug. 2, 1939) (on file at the Franklin D. Roosevelt Library and Museum), *available at* http://www.cfo.doe.gov/me70/manhattan/einstein_letter_photograph.htm).

World War II.[97] Roosevelt responded by funding the first nuclear task force, whose mission was to determine the feasibility of becoming the first nuclear weapon state.[98]

Yet even after the end of World War II, fear of nuclear proliferation fueled the political debates over long-term management of the now robust nuclear program.[99] Two prominent scientists, Vannevar Bush and James B. Conant, proposed draft legislation to establish a twelve-member atomic energy commission, comprised of eight civilians and four military appointees, to manage the nuclear program.[100] With the destruction of Nagasaki and Hiroshima still fresh in people's minds, however, some were uncomfortable releasing nuclear control into civilian hands.[101] In fact, the May-Johnson Bill, originally supported by President Harry Truman, called for strict military control over nuclear science with harsh penalties for security violations.[102] At the same time, an opposing bill, the McMahon Bill, was circulating in the Senate calling for complete civilian control of the nuclear program.[103] Ultimately, the McMahon Bill underwent a series of gradual alterations and by the time it passed both houses it more closely resembled Bush and Conant's early draft legislation.[104]

On August 1, 1946, President Truman signed into force the McMahon Bill, officially titled the Atomic Energy Act of 1946.[105] The Atomic Energy Act of 1946 established the United States Atomic Energy Commission ("AEC") with five full-time civilian presidential appointees overseeing the operational divisions of research, production, engineering, and military application.[106] The Act required the AEC to report to a newly created Joint

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97. Group of the Ministry for Culture and Heritage, *Overview—N.Z. and the Second World War*, N.Z. HISTORY ONLINE (Ministry for Culture and Heritage, Wellington, N.Z. 2005), *available at* http://www.nzhistory.net.nz/node/2334.

98. Office of History & Heritage Res., U.S. Dep't of Energy, *The Manhattan Project: An Interactive History*, *Early Uranium Research (1939-1941)*, http://www.cfo.doe.gov/me70/manhattan/uranium_research.htm (last visited Mar. 19, 2010).

99. Office of History & Heritage Res., Dep't of Energy, *The Manhattan Project: An Interactive History, Picking Horses* http://www.cfo.doe.gov/me70/manhattan/picking_horses.htm (last visited March 19, 2010).

100. Office of History & Heritage Res., U.S. Dep't of Energy, *The Manhattan Project: An Interactive History, Civilian Control of Atomic Energy (1945-1946)*, http://www.cfo.doe.gov/me70/manhattan/civilian_control.htm (last visited Mar. 19, 2010) [hereinafter Civilian Control].

101. *Id.*

102. *Id.*

103. Howard Morland, Comment, *Born Secret*, 26 CARDOZO L. REV. 1401, 1402 (2005).

104. Civilian Control, *supra* note 100.

105. Morland, *supra* note 103, at 1402.

106. Civilian Control, *supra* note 100.

Committee on Atomic Energy ("JCAE") comprised of nine Senate members and nine House Representatives.[107] More importantly, the Atomic Energy Act of 1946 defined a new legal standard for "restricted data," which covered "all data concerning . . . atomic weapons . . . fissionable material [and] fissionable material in the production of power . . ."[108] Prior to World War II, government gag orders for militarily-sensitive information were temporary,[109] but after the Atomic Energy Act of 1946 was enacted, all nuclear information was "born secret."[110] The born secret doctrine was the United States' first long-term gag order and initiated an era of clandestine government decision-making characterized by fear and suspicion.[111]

In fact, the failure of the United States and Great Britain to fully inform their Russian ally about the atomic bomb set the stage for a postwar rivalry between the United States and Russia.[112] Referring to Russia's postwar imposition of communism upon the countries under its military control, British Prime Minister Winston Churchill warned the world that an "iron curtain" was descending upon Eastern Europe.[113] One year later, President Truman announced the "Truman Doctrine," which funded military assistance for nations opposing communism.[114] Believing that a third world war might be imminent, both the United States and Russia began stockpiling nuclear weapons.[115]

B. Atoms for Peace

In an attempt to alleviate growing concern over the United States' immense nuclear arsenal, President Eisenhower gave a speech at the United Nations ("UN") in December 1953 entitled "Atoms for Peace."[116] Although the "Atoms for Peace" proposal suggested the establishment of an international nuclear material stockpile under the control of the UN for the pursuit of peaceful scientific uses, the program's inception had more to do with

107. *Id.*
108. Morland, *supra* note 103, at 1402.
109. *See* Near v. Minnesota, 283 U.S. 697 (1931); United States v. Progressive, Inc., 467 F.Supp. 990 (W.D. Wis. 1979).
110. Morland, *supra* note 103, at 1402.
111. *Id.* at 1401.
112. Office of History & Heritage Res., U.S. Dep't of Energy, *The Manhattan Project: An Interactive History, The Cold War (1945-1990)*, http://www.cfo.doe.gov/me70/manhattan/cold_war.htm (last visited Mar. 19, 2010).
113. *Id.*
114. *Id.*
115. Morland, *supra* note 103, at 1407.
116. Joseph P. Tomain, *Nuclear Futures*, 15 DUKE ENVTL. L. & POL'Y F. 221, 227 (2005).

creating a "check" against the nuclear dilemma than about moving nuclear power away from military purposes.[117] The International Atomic Energy Agency ("IAEA") was organized in 1957 as an independent international agency to promote "safe, secure, and peaceful nuclear technologies."[118] While the science of nuclear power is mostly inseparable from the science of nuclear weapons, what limits a nation's ability to develop nuclear weapons is its access to weapons-grade resources and the technology needed to deliver a weapon. Consequently, the IAEA today is primarily responsible for monitoring the nuclear activities of nonnuclear weapon states to prevent the diversion of nuclear energy from peaceful purposes such as medicine, electricity, and agriculture, to the development of nuclear weapons.[119]

C. Atomic Energy Act of 1954

One year after President Eisenhower's speech before the UN, the United States passed an amendment to the Atomic Energy Act of 1946.[120] The Atomic Energy Act of 1954 amended the previous act for the policy purpose of "promot[ing] world peace, improv[ing] general welfare . . . and strengthen[ing] free competition in private enterprise."[121] The Act allowed private enterprise to participate in nuclear science for the first time and required civilian uses of nuclear materials and facilities to be licensed by the NRC.[122] The Act also required that a bilateral nuclear cooperation agreement be negotiated before any NRC-authorized nuclear technology was sold or exported to a foreign country.[123]

D. Price-Anderson Act of 1957

The Atomic Energy Act alone was not enough to encourage private investment in nuclear power.[124] With nuclear insurance

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117. Dwight D. Eisenhower, U.S. President, Address to the 470th Plenary Meeting of the United Nations General Assembly (Dec. 8, 1953), *available at* http://www.iaea.org/About/history_speech.html.

118. International Atomic Energy Agency, The "Atoms for Peace" Agency, http://www.iaea.org/About/index.html (last visited Mar. 19, 2010).

119. Cochran, *supra* note 25, at 6.

120. Tomain, *supra* note 116.

121. U.S. Nuclear Regulatory Comm'n, Our Governing Legislation, http://www.nrc.gov/about-nrc/governing-laws.html#aea-1954 (last visited Mar. 19, 2010) [hereinafter NRC, Governing Legislation].

122. *Id.*

123. CARL E. BEHRENS, CONG. RESEARCH SERV., NUCLEAR PROLIFERATION ISSUES 7 (2003), *available at* http://fpc.state.gov/documents/organization/20240.pdf.

124. Tomain, *supra* note 116.

unavailable and the potential liability of a nuclear accident nearly limitless, nuclear energy as a business investment simply was not attractive.[125] In 1957, Congress responded to the misgivings of the energy industry with the Price-Anderson Act.[126] The Price-Anderson Act effectively limited the amount of liability that a nuclear operator or manufacturer would incur in the event of an accident by establishing a government indemnification scheme.[127] The following few years were dubbed the Nuclear Bandwagon Market by some scholars, as dozens of new nuclear operators applied for construction permits.[128] Although the Price-Anderson Act was temporary, it has been reauthorized every ten years since its inception.[129]

E. Energy Reorganization Act of 1977

Responding to the persistent effect of the Arab Oil Embargo of 1973–74, the Department of Energy Organization Act of 1977 amended the Energy Reorganization Act of 1974 to coordinate all the energy organizations of the federal government under the DOE, and to withdraw federal support of reprocessing spent nuclear fuel ("SNF").[130] The Carter Administration saw the reprocessing of SNF as a proliferation risk because this reprocessing produced more weapons-grade plutonium (only ten kilograms is needed to make a nuclear weapon), and the administration hoped that if the United States took an antireprocessing stance other countries would follow suit.[131] Few did.[132]

F. Energy Policy Act of 2005

Once commercial nuclear power began to flourish, concern over proliferation resurfaced. In the 1970s and 1980s Congress passed a number of laws that imposed sanctions on countries that attempted to illegally acquire nuclear weapons.[133] The Arms Export Control Act and the Foreign Assistance Act

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125. *Id.*

126. Price-Anderson Act of 1957, Pub. L. No. 85-256, 71 Stat. 576 (codified as amended in various sections of 42 U.S.C. (2000)).

127. Tomain, *supra* note 116.

128. J. SAMUEL WALKER, CONTAINING THE ATOM: NUCLEAR REGULATION IN A CHANGING ENVIRONMENT 1963–1971 ch. 2, 18 (1992); Tomain *supra* note 1166.

129. Tomain, *supra* note 116.

130. U.S. Dep't of Energy, *Origins & Evolution of the Dep't of Energy*, http://www.energy.gov/about/origins.htm (last visited Mar. 19, 2010).

131. Richard B. Stewart, *Nuclear Waste Law and Policy: Fixing a Bankrupt System*, 17 N.Y.U. ENVTL. L.J. 784, 789 (2008).

132. *Id.*

133. BEHRENS, *supra* note123.

contained such provisions.[134] In 1987, Congress enacted the Nuclear Nonproliferation Act to strengthen the Atomic Energy Act's limitation on nuclear exports.[135] The Nuclear Nonproliferation Act required "any country, except the five . . . weapons states, [who wished] to import nuclear technology [to comply with all] IAEA safeguards."[136] For the next thirteen years, the United States Congress remained relatively silent on both the issues of nuclear proliferation and energy in general until the passage of the Energy Policy Act of 2005.[137] The Energy Policy Act of 2005 provided approximately $4.3 billion for the nuclear industry and prohibited the sale, export, or transfer of nuclear materials and technology to any state that sponsors terrorism.[138]

G. Megatons to Megawatts Program

Despite the United State's efforts to prevent nuclear proliferation, there are currently sixteen states with nuclear weapons programs, two states with alleged nuclear weapons programs, and one state with a dismantled nuclear program.[139] Over 189 countries are party to the Nuclear Nonproliferation Treaty of 1968 ("NPT"), but the nuclear-armed signatories include the United Kingdom, the United States, France, Russia, and China.[140] The NPT is commonly described as having three pillars: non-proliferation, disarmament, and the right to use

134. Arms Exp. Control Act, Pub. L. No. 90-629, 82 Stat. 1320 (codified as amended in various sections of 22 U.S.C. (2000)); 22 U.S.C. § 2396(a)(3).

135. Nuclear Nonproliferation Act of 1978, Pub. L. No. 95–242, 92 Stat. 120 (codified as amended in various sections of 22 and 42 U.S.C. (2000)); *see* NRC Governing Legislation, supra note 12121.

136. BEHRENS, *supra* note 123.

137. Energy Policy Act of 2005, Pub. L. No. 109–58, 119 Stat. 594 (codified as various sections of 42 U.S.C.).

138. *Id.*

139. Robert S. Norris & Hans M. Kristensen, *U.S. Nuclear Forces, 2008*, BULL. OF THE ATOMIC SCIENTISTS, March/April 2008 50, 50–53, *available at* http://thebulletin.metapress.com/content/pr53n270241156n6/fulltext.pdf; Robert S. Norris & Hans M. Kristensen, *Russian Nuclear Forces, 2008*, BULL. OF THE ATOMIC SCIENTISTS, May/June 2008 54, 54–57, *available at* http://thebulletin.metapress.com/content/t2j78437407v3qv1/fulltext.pdf; Norris, Robert S. Norris & Hans M. Kristensen, *French Nuclear Forces*, *2008*, BULL. OF THE ATOMIC SCIENTISTS, Sept./Oct. 2008, at 52, 52–54, *available at* http://thebulletin.metapress.com/content/k01h5q0wg50353k5/fulltext.pdf; Robert S. Norris & Hans M. Kristensen, Natural Res. Def. Council, *Global Nuclear Stockpiles, 1945-2006*, BULL. OF THE ATOMIC SCIENTISTS, July/Aug. 2006 64, 64–67, *available at* http://thebulletin.metapress.com/content/c4120650912x74k7/fulltext.pdf [hereinafter *Global Nuclear Stockpiles*].

140. Canadian Foreign Affairs and International Trade, The Nuclear Non-Proliferation Treaty, http://www.international.gc.ca/arms-armes/nuclear-nucleaire/npt-tnp.aspx (last visited Mar. 19, 2010).

nuclear technology peacefully.[141] India, North Korea, Pakistan, and Israel are nuclear-armed countries that are nonsignatories to the NPT; however, Israel has never publicly admitted to having nuclear weapons.[142] South Africa dismantled its nuclear weapons program in the 1990s.[143] Belgium, Germany, Italy, the Netherlands, Turkey, Canada, and Greece are nuclear-sharing states.[144] The following countries have nuclear power reactors: the United States, France, Japan, Russia, Germany, South Korea, Ukraine, Canada, the United Kingdom, Sweden, China, Spain, Belgium, Taiwan, India, the Czech Republic, Switzerland, Bulgaria, Finland, Slovakia, Brazil, South Africa, Hungary, Romania, Mexico, Lithuania, Argentina, Slovenia, the Netherlands, Pakistan, Armenia, and Iran.[145]

Since 1994, the United States has purchased Russian nuclear warheads to fuel U.S. nuclear reactors through a commercially-financed partnership called "Megatons to Megawatts."[146] Acting as executive agent for Russia, Techsnabexport, Inc. ("TENEX") recycles Russian warheads by converting them into low-enriched uranium ("LEU") and then ships the LEU to the United States.[147] The executive agent for the United States, USEC Inc., purchases the fuel, markets it to USEC's utility customers, and sells TENEX an equal quantity of unenriched uranium for use in Russia's nuclear reactors.[148] This recycling program has eliminated over 20,000 nuclear warheads since its inception and has provided electrical fuel for one in every ten American homes.[149]

IV. CULTURAL PERCEPTIONS OF RISK AND FEAR

Different cultures often have different perceptions of risk and fear.[150] Consider health risks for example—most Americans like ice in their soft drinks, but many Germans believe putting

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141. *Id.*
142. *Global Nuclear Stockpiles*, *supra* note 139, at 64.
143. Frank V. Pabian, *South Africa's Nuclear Weapon Program: Lessons for U.S. Nonproliferation Policy*, 3 THE NONPROLIFERATION REV. 1, 1 (1995), *available at* http://cns.miis.edu/npr/pdfs/31pabian.pdf.
144. HANS M. KRISTENSEN, NATURAL RES. DEF. COUNCIL, U.S. NUCLEAR WEAPONS IN EUROPE (2005), *available at* http://www.nrdc.org/nuclear/euro/euro.pdf.
145. World Nuclear Ass'n, World Nuclear Power Reactors & Uranium Requirements (Feb. 1, 2010), http://www.world-nuclear.org/info/reactors.html.
146. USEC Inc., Nuclear Nonproliferation, Megatons to Megawatts, http://www.usec.com/megatonstomegawatts.htm (last visited Mar. 19, 2010).
147. *Id.*
148. *Id.*
149. *Id.*
150. Cass R. Sunstein, *Precautions Against What? The Availability Heuristic and Cross-Cultural Risk Perception*, 57 ALA. L. REV. 75, 88 (2005).

ice in a soft drink is unhealthy.[151] Likewise, people often have different perceptions of separate aspects of related risks, even within the same culture. For example, the French public is highly accepting of nuclear power and its potential for collateral risks.[152] Seventy-five percent of French electricity is generated from nuclear power plants.[153] Yet, when it came time to develop a nuclear waste facility, large demonstrations and riots erupted all over France.[154]

Differences in cultural perceptions of risk and fear can often be explained by: (1) familiarity with positive or negative paradigms, (2) social influence and group polarization, (3) media preoccupation, and (4) actual differences in risk among cultural groups.[155] Studies show that the U.S. public's attitude toward nuclear energy is formed almost entirely by the public's perception of the technology, rather than by politics or by demographics such as income, education, and gender; but the media may play a role in influencing many Americans' perceptions of nuclear technology.[156]

A. The Effects of Three Mile Island and Chernobyl

On the morning of March 28, 1979, a series of mechanical and judgmental errors resulted in a leak in the protective blanket of water surrounding reactor core #2 at Three Mile Island ("TMI"), Pennsylvania.[157] Believing the problem to be minor, Metropolitan Edison, the plant's operator, announced that there was no risk of danger to the public.[158] By the end of the next day, two-thirds of the reactor's water had escaped; and part of the core melted.[159] Just two days later, a high radiation reading was recorded above the vent stack.[160] Responding to the possibility of

151. JOSEPH HENRICH ET AL., GROUP REPORT: WHAT IS THE ROLE OF CULTURE IN BOUNDED RATIONALITY?, BOUNDED RATIONALITY: THE ADAPTIVE TOOLBOX 343, 353 (Gerd Gigerenzer & Reinhard Selten eds., 2001).

152. Amanda Leiter, *The Perils of a Half-Built Bridge: Risk Perception, Shifting Majorities, and the Nuclear Power Debate*, 35 ECOLOGY L.Q. 31, 67 (2008).

153. *Id.*

154. *Id.*

155. Sunstein, *supra* note 150, at 75, 95, 97–100.

156. ERIC S. BECKJORD ET AL., THE FUTURE OF NUCLEAR POWER: AN INTERDISCIPLINARY MIT STUDY 6 (2003), *available at* http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf; PETER S. HOUTS ET AL., THE THREE MILE ISLAND CRISIS: PSYCHOLOGICAL, SOCIAL, AND ECONOMIC IMPACTS ON THE SURROUNDING POPULATION 84–85 (1988) (The Penn. State Univ. Press, 1988) (showing that the majority of TMI evacuees based their decision to evacuate on media coverage, but that the evacuees perception of the quality of media coverage was dependant upon their pre-evacuation perception of the TMI nuclear power plant).

157. HOUTS ET AL., *supra* note 156, at ix.

158. *Id.*

159. *Id.*

160. *Id.* at 3.

public health consequences, the Governor recommended evacuating pregnant women and preschool children within five miles of TMI, closing local schools, and that citizens within ten miles should stay indoors.[161]

What followed can only be described as something short of hysteria. Local towns ran warning sirens.[162] Some people left messages on their homes believing they would never return.[163] The media covered the event nonstop focusing on the uncertainty with respect to how much radiation had been released, and the possibility of a hydrogen bubble causing a nuclear explosion.[164] More than 140,000 people left their homes.[165] The public outcry that followed the TMI crisis nearly forced General Public Utility, the parent company of the plant's operator, into bankruptcy.[166] As a result of this public outcry, only one new nuclear power plant was successfully completed after the TMI incident, and it was ultimately shut down prior to generating its first watt of electricity because of persistent protesting.[167]

But TMI was not the only nuclear incident to influence public perception. On April 26, 1986, a flawed reactor design coupled with operator error caused Unit 4 of the Chernobyl nuclear power plant in the Union of Soviet Socialist Republics (USSR, present day Ukraine) to explode, rupturing the reactor's containment vessel.[168] The subsequent fire burned for days afterwards, emitting large amounts of radioactive material such as Iodine-131 and Cesium-137 into the environment.[169] The

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161. HOUTS ET AL., *supra* note 1566, at 3.
162. *Id.*
163. *Id.*
164. *Id.* at 4–5.
165. HOUTS ET AL., *supra* note 156, at x.
166. TMI caused no deaths or injuries and no significant environmental effects other than the minimal amount of radioactive gas released. *Id.*; Eric R. Pogue, *The Catastrophe Model of Risk Regulation and the Regulatory Legacy of Three Mile Island and Love Canal*, 15 PENN ST. ENVTL. L. REV. 463, 470 (2007); The Rep. of the President's Comm'n on the Accident at Three Mile Island, The Need for Change: The Legacy of TMI 13 (Oct. 1979).
167. The Shoreham nuclear power plant was completed in 1984 and cost approximately six million dollars. Ultimately, the cost of the plant was passed on to the citizens of the state in exchange for shutting the plant down. U.S. NRC, INFO. DIGEST, *supra* note 28, app. B; *Shoreham Action Is One of Largest Held Worldwide: 15,000 Protest L.I. Atom Plant; 600 Seized 600 Arrested on L.I. as 15,000 Protest at Nuclear Plant*, NEW YORK TIMES (June 4, 1979), *available at* http://select.nytimes.com/gst/abstract.html?res=F20D11FD3E5D12728DDDAD0894DE405B898BF1D3.
168. D. KINLEY III, ED., DIV. OF PUB. INFO., INT'L ATOMIC ENERGY AGENCY, CHERNOBYL'S LEGACY: HEALTH ENVTL. AND SOCIO-ECON. IMPACTS AND RECOMMENDATIONS TO THE GOVERNMENTS OF BELARUS, THE RUSSIAN FEDERATION, AND UKRAINE 10 (2d. ed. 2005), *available at* http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf.
169. *Id.*

Chernobyl accident released 400 times more radioactive pollution than the bomb dropped on Hiroshima but 100 to 1,000 times less than the sum of radiation released from world-wide nuclear testing in the 1950s and 60s.[170]

Following the accident over 600,000 "liquidators" took part in the recovery effort, and approximately 336,000 people were relocated.[171] Chernobyl was located in a dense forest, and ninety percent of the fallout was filtered by the forest and concentrated in the leaf litter.[172] Thirty-nine short-term deaths were caused within a few months of the accident.[173] Out of the 4,000 children who developed thyroid cancer from radiation exposure, fifteen have died.[174] Although the international scientific consensus estimates that as many as 100,000 fatal cancers may be expected when the exposed population nears old age, this estimate is only slightly above the expectation for an unexposed population, leading some to believe that the Chernobyl studies are inconclusive.[175]

In contrast to the TMI accident, the Ukraine government supported the relocation of 336,000 people rather than only that portion of the population with the highest risk, such as preschool-aged children.[176] Other governments might have considered the adverse effects of public exposure to low-level radiation as outweighed by the psychological, sociological, and economic impact of relocating 336,000 people.[177] On the other hand, it is quite possible that the risks faced by TMI residents were significantly different from those faced by the Ukrainians. Clearly, the Soviet nuclear operators were less trained than their American counterparts, and Chernobyl Unit 4 was not the only reactor at the Chernobyl site.[178]

Together, the Chernobyl and TMI accidents incited a passionate group of anti-nuclear protestors who were

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170. Int'l Atomic Energy Agency, Facts: The Accident was by Far the Most Devastating in the History of Nuclear Power, http://www.iaea.org/Publications/Booklets/Chernoten/facts.html (last visited Mar. 19, 2010).

171. KINLEY, *supra* note 168.

172. Int'l Atomic Energy Agency, Facts: Low-Level Radioactive Contamination will Persist for Decades, http://www.iaea.org/Publications/Booklets/Chernoten/five.html (last visited Mar. 19, 2010).

173. KINLEY, *supra* note 168, at 14.

174. *Id.* at 16.

175. *Id*; World Nuclear Ass'n, Chernobyl Myths and Reality, http://www.world-nuclear.org/why/chernobyl.html (last visited Mar. 19, 2010).

176. HOUTS, ET AL., *supra* note 157.

177. Sunstein, *supra* note 150, at 83.

178. World Nuclear Ass'n, Chernobyl Accident, http://www.world-nuclear.org/info/chernobyl/inf07.html (last vistited Mar. 19, 2010) [hereinafter World Nuclear Ass'n, Chernobyl Accident].

instrumental in causing the shutdown of the Shoreham, Yankee Rowe, Millstone I, Rancho Seco, Maine Yankee, and about a dozen other nuclear power plants in the United States.[179] Universities, too, responded by closing down their nuclear engineering programs.[180] By the mid-1990s, the number of nuclear engineering programs in the United States dropped from over forty-seven to less than twenty-five.[181] But the Chernobyl and TMI accidents also spurred an unexpected cooperation between the United States and Russia.[182] By 1989, over 1,000 Soviet nuclear engineers had traveled to the United States to compare nuclear safety programs and share information and experience.[183] As a result, both Russian and American nuclear operators have improved their safety standards and operational/maintenance efficiency—this significantly lowers the operating costs of nuclear power.[184]

B. The Effect of Pop Culture and Early Childhood Education

Yet even before TMI and Chernobyl, the relative rift in the public's perception of nuclear technology could already be seen in pop culture and education. Responding to the growing concerns of the Cold War era, Congress enacted the Federal Civil Defense Act of 1950 to fund projects for the protection of the public from atomic attacks.[185] Although building fallout shelters for the entire public proved uneconomical, the Civil Defense Administration invested in civil education programs that printed pamphlets teaching people how to build their own fallout shelters, instituted warning systems, and taught children how to respond to atomic attacks.[186]

The Civil Defense Administration also invested heavily in pop culture, underwriting films and novels such as the 1951 film

179. Eesha Williams, *Nuke Fight Nears Decisive Moment: Under Pressure from the Public, the Vt. Legislature can Close the Vt. Yankee Nuclear Power Plant*, THE VALLEY ADVOCATE, Aug. 28, 2008, *available at* http://www.valleyadvocate.com/article.cfm?aid=8218.

180. Michael L. Corradini et. al., *The Future of Nuclear Engineering Programs & University Research & Training Reactors* 9 (Dep't of Energy, May 2009), *Final Draft available at* http://www.ne.doe.gov/nerac/neracPDFs/finalblue.pdf.

181. *Id.*

182. World Nuclear Ass'n, Chernobyl Accident, *supra* note 178.

183. *Id.*

184. *Id.*; John Rich, Dir., World Nuclear Ass'n, *The Future of Nuclear Energy in an Era of Environmental Crisis and Terrorist Challenge*, IAEA Symposium on Verification and Nuclear Materials Sec. (Vienna, Nov. 2001), http://www.world-nuclear.org/John_Ritch_speeches/John_Ritch_iaeanov2001.html.

185. 50 U.S.C.A. App. §§ 2251 et seq. (*repealed* 1994).

186. U.S. GEN. ACCOUNTING OFFICE, B-133209, *Activities and Status of Civil Defense in the United States* (Dep't of the Army, Oct. 26, 1971).

by Archer Productions, *Duck and Cover*.[187] *Duck and Cover* featured an animated turtle that taught children how to duck under their desks or go inside at the first sign of an explosion.[188] Although the Civil Defense Administration was eventually succeeded by the Federal Emergency Management Agency and Homeland Security, the Department of Defense continued funding pop culture projects even after the dissolution of the Civil Defense Administration.[189] As it turned out, nuclear fiction was a best-seller even without government support. Today, Americans still celebrate many of these pop culture icons such as *Captain Atom* (a comic book superhero who gained his power from a nuclear explosion) and the 1985 edition of *Superman* (in which the "Man of Steel" had a nightmare about being the only survivor of a nuclear holocaust).[190] Chernobyl and Three Mile Island also inspired a genre of pop culture novels that featured accidents involving nuclear reactors, civilian laboratories, and nuclear power plant waste such as Jerry Earl Brown's *Under the City of Angels* and Jack Womack's *Ambient*.[191] America's trouble with nuclear waste policy suggests that these government sponsored programs and pop culture fixations may have had a perverse effect on an entire generation's perception of nuclear power.

V. NUCLEAR WASTE

A. The Nuclear Waste Policy Act

Enacted in 1982, the Nuclear Waste Policy Act ("NWPA") required the DOE to identify a list of suitable sites for two geological repositories (one in the eastern United States and one in the western United States) and establish the criteria for their selection.[192] The capacity of the first repository was limited to

187. U.S. Fed. Civil Def. Admin., DUCK AND COVER (Archer Productions 1951), *available at* http://www.archive.org/details/DuckandC1951.

188. *Id.*

189. *See* LAURA MCENANEY, CIVIL DEFENSE BEGINS AT HOME: MILITARIZATION MEETS EVERYDAY LIFE IN THE FIFTIES (Princeton Univ. Press 2000).

190. *See* Paul Brian, Wash. State Univ., *Nuke Pop*, http://www.wsu.edu/~brians/nukepop/index.html (last visited Mar. 19, 2010) (depicting a wide collection of images from popular culture comic books and novels); Paul Brian, *Nuclear Holocausts: Atomic War in Fiction 1894–1985* (Kent State Univ. Press, 1987), *available at* http://www.wsu.edu/~brians/nuclear/index.htm.

191. JERRY EARL BROWN, UNDER THE CITY OF ANGELS (Bantam Books, May 1981); JACK WOMACK, AMBIENT (Weidenfeld & Nicolson, NY 1987).

192. Michael Mullet, *Financing for Eternity the Storage of Spent Nuclear Fuel: A Crisis of Law and Policy Precipitated by Elec. Deregulation Will Face New President*, 18 PACE ENVTL. L. REV. 393 (Summer 2001); U.S.C. §§ 10132(a)–(b)(1)(C) (1982) *amended or repealed by* Nuclear Waste Policy Amendments Act of 1987, Pub. L. No. 100–202, 101 Stat. 1329–104 and Pub. L. No. 100–203, 5011(b), 101 Stat. 1330–228.

70,000 metric tons of heavy metal (MTHM): 63,000 MTHM for civilian SNF and 7,000 MTHM for defense-related waste.

The Act required the DOE to begin accepting SNF by January 31, 1998.[193] Once the site was chosen, the DOE would have the responsibility to construct and close the repository. The NRC was given responsibility to oversee the licensing process.[194] The repositories would be paid for out of the Nuclear Waste Fund, which required all commercial nuclear generators to pay one-tenth (one mil) of a cent for every kilowatt-hour of nuclear energy used (approximately $572 million per year) and a one-time fee for expenses incurred prior to the fund's establishment.[195]

In 1986, the three sites approved for site characterization by the President were Deaf Smith County, Texas; Hanford, Washington; and Yucca Mountain, Nevada.[196] Unbeknownst to many, however, the Hanford site was secretly contaminated, the full extent of which would not be unclassified for many years.[197] The Texas site was also laden with problems as it had the greatest potential for human harm due to the nearest population center being located directly downwind from the repository. It was located in a salt formation which would advance the degradation of the waste packages and prevent their removal once inserted, and all of the land had to be purchased or acquired via eminent domain.[198] Yucca Mountain, on the other hand, was strongly favored by the DOE, which initially started studying the site in 1977, just one week after the department's organization.[199]

In 1987, Congress passed the Nuclear Waste Policy Act Amendment ("NWPAA") which effectively eliminated the DOE's

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193. Mullet, *supra* note 192, at 399.

194. 42 U.S.C. §§ 10141(b), 10191(2) (2000).

195. 42 U.S.C. § 1022(a)(2)–(3) (West 1995).

196. 51 C.F.R. § 19783 (June 2, 1986); Nevada v. Herrington, 827 F.2d 1394, 1397 (9th Cir. 1987).

197. *See* In Re Hanford Nuclear Reservation Litig., 292 F.3d 1124 (9th Cir. 2002); Thomas E. Marceau et.al., Hanford Cultural and Historic Res. Program, Dep't of Energy, DOE/RL-97-1047, ISBN 1-57477-133-7, *History of the Plutonium Prod. Facilities at the Hanford Site Historic Dis.t, 1943-1990*, HANFORD SITE HISTORIC DIST., (*prepared by* Battelle Press, Columbus Ohio, June 2002), *available at* http://www.hanford.gov/doe/history/docs/rl-97-1047/index.pdf; Laura A. Hanson, *Waste Contamination of Soil and Groundwater at the Hanford Site*, (Univ. of Idaho, Nov. 2000), *available at* http://www.agls.uidaho.edu/etox/resources/case_studies/HANFORD.PDF; Office of Envtl. Mgmt., Dep't of Energy, DOE/EM-0001, *Status of Envtl. Mgmt. Initiatives to Accelerate the Reduction of Envtl. Risks and Challenges Posed by the Legacy of the Cold War*, ANN. REP. TO CONG. 23 (Jan. 2009).

198. Office of Civilian Radioactive Waste Mgmt., U.S. Dep't of Energy, DOE/RW-0069, *Envtl. Assessment: Deaf Smith County, Texas*, vol. 2, 6–85 (May 1986) (on file in the Univ. of Houston, Clear Lake Library).

199. Office of Civilian Radioactive Waste Mgmt., U.S. Dep't of Energy, *Yucca Mountain Repository*, http://www.ymp.gov/ym_repository/index.shtml (last visited Mar. 19, 2009).

authority to build a second repository and bypassed the site selection process for the first repository by allowing the Secretary of Energy to proceed with the site characterization of Yucca Mountain.[200] Thus, although the NWPAA did much to advance the construction of a repository, it left no clear alternative short of Congressional action in the event the primary site later became unsuitable.

Thirty-two years of research and ten billion dollars later, scientists discovered that the Yucca Mountain area may have been damaged from nuclear testing during WWII, and is therefore scientifically less suitable as a repository location than originally believed.[201] As a result, the progress of the project was significantly delayed by litigation over the EPA's safety standards for Yucca Mountain.[202] A number of states chose to take issue with the EPA's "25 millirem for 10,000 year"[203] rule, claiming the DOE needed to show safe radiation levels beyond 10,000 years, even though regulating that far into the future is somewhat unreasonable.[204] Today, the EPA divides the safety rule into two time frames: fifteen millirems for the first 10,000 years and 350 millirems for the next 990,000 years.[205] The irony of the Yucca Mountain safety litigation, however, is that scientists predict radiation exposure from the site to be less than one millirem a year for the next one million years.[206]

Having nowhere to put the SNF the DOE allowed the January 31, 1998 deadline to pass—DOE then began incurring liabilities at a rate of several hundred million dollars per year for failing to take title to the waste.[207] Yet, even in the face of

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200. Robert Ressetar, *The Yucca Mountain Nuclear Waste Repository from a Federalism Perspective*, 23 J. LAND RESOURCES & ENVTL. L. 219, 232 (2003).

201. J. Fairley, E. Sonnenthal, *Preliminary Conceptual Model of Flow Pathways Based on Cl-36 and Other Entl. Isotopes, in Unsaturated Zone Model*, at 399 (G.S. Bodvarsson & T.M. Bandurraga eds., 1996); *see* G.S. Bodvarsson, T.M. Bandurraga, *Dev. and Calibration of the Three-Dimensional Site-Scale Unsaturated Zone Model of Yucca Mountain, Nev.*, at 265 (1996).

202. Natural Res. Def. Council, Inc. v. EPA, 824 F.2d 1258, 1263 (1st Cir. 1987); Nuclear Energy Inst., Inc. v. EPA, 373 F.3d 1251, 1266 (D.C. Cir. 2004).

203. Millirems per year as used by the EPA measures the average annual public exposure to radiation from Yucca Mountain. In comparison, a person is exposed to one millirem of radiation by watching 3 hours of color television a day for a year, and smoking just one cigarette a day per year exposes a person to approximately thirty-six millirems. Office of Civilian Radioactive Waste Mgmt., Dep't of Energy, DOE/YMP-062, *The Nat'l Repository at Yucca Mountain: Solving a Nat'l Problem Now* (Las Vegas, Nev., July 2008), *available at* http://www.ocrwm.doe.gov.

204. 824 F.2d 1258 (1st Cir. 1987).

205. 40 C.F.R § 197 (Aug. 22, 2005).

206. Office of Civilian Radioactive Waste Mgmt., Dep't of Energy, *Yucca Mountain Repository*, *http*://www.ocrwm.doe.gov/uploads/1/SER.PDF (last visited Mar. 19, 2010).

207. The Liability of the DOE to take title to SNF arose out of the standard contracts between the DOE and the Nuclear Waste Generators as required by the NWPA. Letter from Sec'y of Energy, U.S. Dep't of Energy, to Richard B. Cheney, Pres. Of the Senate

increased controversy and reduced funding, the DOE managed to file an application for a construction license in 2008. Should the project be granted a construction license and funded by Congress, however, the earliest that construction could begin is 2013.[208]

B. Rate of Nuclear Waste Accumulation

Due to the fact that no repository for permanent SNF disposal exists, more than 58,000 MTHM of commercial SNF and 12,800 MTHM of defense-related SNF are being "temporarily" stored at 126 commercial power plants and DOE storage sites across the nation.[209] Provided that no new power plants are built, 130,000 MTHM of commercial SNF will need a disposal plan by the time the licenses of all currently-operating nuclear power plants expire.[210] Deployment of enough new nuclear reactors in the United States to displace one U.S. carbon dioxide wedge would generate enough SNF to require another Yucca Mountain every twelve years.[211] As a result, in 2008, the DOE discretely modified the cost of its Civilian Radioactive Waste Management program to include the funding necessary to increase Yucca Mountain's storage capacity from 70,000 MTHM to 122,100 MTHM.[212]

Meanwhile, the DOE's liability to nuclear waste generators for breach of its Standard Disposal Contracts is nearing seven billion dollars.[213] This amount is expected to grow by several hundred million dollars each year the construction of a repository is delayed.[214] Yet, after twenty-nine years of research, the federal government may be attempting a change of direction.[215] In March 2009, the Obama Administration proposed a federal budget plan that eliminated all funding for Yucca Mountain

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(March 6, 2007), *available at* http://www.ocrwm.doe.gov/info_library/newsroom/documents/2007bill.pdf [hereinafter Cheney Letter].

208. Office of Civilian Radioactive Waste Mgmt., Dep't of Energy, Q. PROGRESS REP. TO CONG.: 2ND AND 3RD QUARTERS FY 2008, 1, *available at* http://www.ocrwm.doe.gov/info_library/program_docs/quarterly_reports/Quarterly_Report_2nd_and_3rd_FY_2008.pdf.

209. Office of Civilian Radioactive Waste Mgmt., Dept. of Energy, *The Rep. to the President and the Cong. by the Sec'y of Energy on the Need for a Second Repository*, DOE/RW-0595 1 (December 2008), *available at* http://www.rw.doe.gov/info_library/program_docs/Second_Repository_Rpt_120908.pdf; Leiter, *supra* note 152, at 61.

210. *Id.*

211. Leiter, *supra* note 152.

212. Office of Civilian Radioactive Waste Mgmt., Dep't of Energy, DOE/RW-0591, *Analysis of the Total Sys. Life Cycle Cost of the Civilian Radioactive Waste Mgmt. Program: Fiscal Year 2007* v (July 2008).

213. Cheney Letter, *supra* note 207; *see* 10 C.F.R. § 961.11 (Apr. 7, 1983).

214. *Id.*

215. *Id.*

except for what is needed to answer inquiries from the Nuclear Regulatory Commission "while the Administration devises a new strategy toward nuclear waste disposal."[216] Although such an action will delay progress at Yucca Mountain, unless the NWPA is repealed or amended, it is not likely that the project will be completely terminated. Still, with Yucca Mountain's construction further delayed and nuclear generators running out of on-site interim storage space, the NRC may choose not to issue any new operating licenses until there is a clear path for the disposal of the new fleet's SNF.

VI. THE EFFECT OF CO_2 PERMIT PRICE CHANGES (IN THREE STAGES)

A. Stage 1: The Initial Effects of CO_2 Permit Prices

Once a carbon tax is initiated, utilities are likely to look toward natural gas as a least-cost and lower-risk alternative to coal.[217] Initially, electric prices are not expected to substantially increase since fairly cheap natural gas plants can quickly replace coal-fired plants.[218] However, because natural gas production in the United States has already peaked, the volatile nature of natural gas prices would likely make nuclear power plants price competitive by 2030.[219] Although liquefied natural gas ("LNG") imports are an option, LNG is costlier and produces more GHGs than regular natural gas.[220] Generally, an LNG plant would produce about half the carbon of a coal-fired plant, but the combustion and processing required to transport LNG adds another 20 to 40% to GHG emissions.[221]

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216. Office of Mgmt. and Budget, ISBN: 978-0-16-082552-1, *A New Era of Responsibility*, ANN. BUDGET PROPOSAL FY2010, 65, (March 2009); Gerrard, *supra* note 3, at 3.

217. Gulf Coast Power Ass'n. *supra* note 10.

218. EIA, ANNUAL ENERGY OUTLOOK 2009, *supra* note 29, at 72.

219. *Id.*

220. *See* Jensen Assoc., CEC-200-2007-017, *The Outlook for Global Trade in Liquefied Natural Gas Projections to the Year 2020*, 15 (Cal. Energy Comm'n Consultant Rep., Aug. 2007), *available at* http://www.energy.ca.gov/2007publications/CEC-200-2007-017/CEC-200-2007-017.PDF; Ratepayers for Affordable Clean Energy (RACE), *LNG and Global Warming*, http://www.raceforcleanenergy.org/article.php?list=type&type=12 (last visited Mar. 19, 2010) [hereinafter Ratepayers] (listing a conservative estimate that LNG adds 20–40% to regular natural gas combustion); Richard Heede, Envtl. Def. Ctr., *LNG Supply Chain Greenhouse Gas Emissions for the Cabrillo Deepwater Port: Natural Gas from Austl. to Cal.*, 20 (Climate Mitigation Services, Santa Barbara, Cal. May 7, 2006), *available at* http://www.raceforcleanenergy.org/downloads/Heede%20climate%20change%20report.pdf (claiming that the LNG supply chain adds 35 – 50% to the regular combustion of natural gas).

221. Ratepayers, *supra* note 220; Heede, *supra* note 220.

Once increased demand makes natural gas less competitive, future plant construction decisions will largely depend on expectations of interest rates, material availability, and CO_2 market trading rates.[222] Clean coal, nuclear, and renewable technologies are capital-intensive and are sensitive to interest rates and cost-recovery periods.[223] In fact, capital expenditures make up the vast majority of a nuclear reactor's cost.[224] Because nuclear power plants have high capital costs, nuclear plants are designed to have larger generating capacities and longer operating lives than other types of power plants (except some hydroelectric plants like the Hoover Dam).[225] Thus, nuclear power plants have a cost-recovery period of between forty and sixty years, which is significantly longer than other types of plants. Unlike fossil fuel plants, the fuel costs of a nuclear power plant are nominal.[226]

1. Cost Structure Comparison of Nuclear Energy

Assuming that the problem with radioactive waste does not become inhibitive of nuclear power expansion, modern studies indicate that nuclear power could compete with coal at a carbon tax rate of fifteen to twenty dollars per metric ton.[227] Likewise, nuclear power can compete with natural gas at a carbon tax greater than thirty dollars.[228] If the carbon tax rate rises higher than forty-five dollars per metric ton, nuclear power would be competitive with all other types of power, even without Energy Policy Act incentives.[229] Yet because no advanced Generation III+ nuclear power plants have been built in the United States, it is still possible that regulatory delays could increase plant construction costs despite Japan's proven ability to timely construct these modular plants.

Earlier studies that did not include nuclear power's recent advances in operating and construction efficiency, however, indicate that it would take a carbon tax of fifty to one hundred

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222. *Id.*

223. Energy Info. Admin, U.S. Dep't of Energy, Impacts of Elec. Power Indus. Restructuring on the U.S. Nuclear Power Indus. (Oct. 18, 2002) http://www.eia.doe.gov/cneaf/electricity/chg_str_fuel/html/chapter2.html.

224. *Id.*

225. Milton B. Whitfield, *Electricity Restructuring in the USA and its Effects on the Nuclear Industry*, (The Uranium Inst., Twenty-Second Ann. Intl. Symposium, 1997), *available at* http://www.world-nuclear.org/sym/1997/whitf.htm (showing recovery period of a nuclear power plant).

226. *Id.*; Catherine Morris, Dir., *Nuclear Power Joint Fact-Finding Executive Summary 2007*, 11 (The Keystone Center, June 2007) (showing fuel costs to be nominal).

227. PARKER & HOLT, *supra* note 69, at 22.

228. *Id.*

229. CBO, NUCLEAR POWER'S ROLE, *supra* note 36, at 2.

dollars per metric ton to make nuclear power competitive with other types of power.[230]

Furthermore, a few practical matters make investing in nuclear power plants difficult. Nuclear power plants take decades to plan and construct.[231] Since the early 1960s and 1970s, the economy of the United States has changed drastically.[232] The United States no longer has the domestic industry necessary to produce the larger steel components of a nuclear power plant and would have to rely on Japan Steel Works Ltd. to make the primary containment vessel (the structure that prevents radiation from leaking into the atmosphere).[233] Japanese Steel Works is currently the only steel plant in the world that is large enough to make nuclear reactor vessels.[234] The company can fabricate four containment vessels per year, and already has a world-wide waiting list.[235]

B. Stage 2: The Effects of Government Policy

Assuming that the nuclear industry becomes price competitive and overcomes the practical obstacles of building enough new nuclear plants to keep up with or exceed the retiring fleet, how will fluctuating permit prices affect the nuclear industry? If government emission restrictions progress faster than renewable fuel and CCS technology, nuclear plants will be the most attractive power source in the "dirtiest" air pollution zones. Utility investment choices will largely depend on the investor's faith in continued government support of renewable technologies.[236]

If technology advances faster than government GHG restrictions, nuclear power's continued feasibility will depend on the magnitude of the technological advancement.[237] If the

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230. ERIC S. BECKJORD ET. AL., THE FUTURE OF NUCLEAR POWER: AN INTERDISCIPLINARY MIT STUDY 7 (2003), *available at* http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf.

231. Cochran, *supra* note 25, at 11.

232. Donald A. Coffin, *The State of Steel*, 78 IND. BUS. REV. 1, 3 (Spring 2003), *available at* http://www.ibrc.indiana.edu/ibr/2003/spring03/pdfs/1_steel.pdf.

233. Yoshifumi Takemoto & Alan Katz, *Samurai-Sword Maker's Reactor Monopoly May Cool Nuclear Revival*, BLOOMBERG.COM, March 12, 2008, http://bloomberg.com/apps/news?pid=20601109&sid=aaVMzCTMz3ms&refer=home; CBO, NUCLEAR POWER'S ROLE, *supra* note 36, at 30.

234. Takemoto & Katz, *supra* note 233.

235. *Id.*

236. *See* State Energy Conservation Office, Texas Wind Energy Incentives, http://www.seco.cpa.state.tx.us/re_wind-incentives.htm (last visited Mar. 19, 2010); WINDUSTRY'S CMTY. WIND TOOLBOX, CHAPTER 16: PUBLIC POLICY FOR COMMUNITY WIND, http://windustry.advantagelabs.com/sites/windustry.org/files/Policy.pdf.

237. *See* R. LARRY REYNOLDS, BASIC MICROECONOMICS: AN OUTLINE Part II Ch. 8 1, 1–4 (2005), http://www.boisestate.edu/econ/lreynol/web/PDF/short_8_Dem_supp.pdf

magnitude of technological advancement is less than the shift in electrical demand, prices will continue to increase and nuclear power will remain competitive.[238] But, where the magnitude of the technological advancement is greater than the increase in demand, the technologically advanced renewable source or CCS technology will become more attractive than nuclear power.[239] This scenario begs the question: Is investing in long term nuclear power projects worth the risk? Clearly, government policy can and probably will "manipulate" the "free" market. If the government primarily uses a carbon cap to incentivize renewable fuel technologies rather than lowering carbon dioxide emissions, nuclear power may be too risky an investment.

C. Stage 3: Falling Permit Prices

Assuming that a cap and trade system is successful in lowering carbon emissions, eventually the market price of a carbon permit will begin to level off.[240] The idea is that the energy industry will be frozen in time with whatever technologies are currently working until the population grows enough to make energy research lucrative once more.[241] This is largely because the marginal abatement cost increases when electrical prices increase faster than it decreases when electrical prices fall.[242] With a cap and trade system still looming on the horizon, no one can be sure exactly how the system will be implemented. Since permits would be marketable, taxing permit sales may become irresistibly attractive.[243]

Although the United States generally abstains from double taxation, there is no guarantee that a cap and trade system will not tax the "tax."[244] Double taxation would create a significant monetary incentive to interfere with falling permit prices by prematurely and continually reducing the emission cap.[245] Can a

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(discussing the difference between a change in quantity demanded and a shift in the demand or supply curve).

238. *Id.* at 4–12 (showing how supply shifts due to technological advancement, and how demand shifts due to population increases).

239. *Id.*

240. Fan Zhang, *Does Uncertainty Matter? A Stochastic Dynamic Analysis of Bankable Emission Permit Trading for Global Climate Change Policy* 2–9 (World Bank Policy Research, Working Paper No. 4215, 2007), *available at* http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2007/04/19/000016406_20070419123848/Rendered/INDEX/wps4215.txt.

241. *Id.* at 9.

242. *Id.*

243. *See "Carbon Cap-and-Trade" a Double Tax on Consumers,* TULSA TODAY, Mar. 4, 2009, http://www.carbonoffsetsdaily.com/news-channels/usa/carbon-cap-and-trade-a-double-tax-on-consumers-4993.htm.

244. *Id.*

245. *Id.*

responsively sluggish nuclear power industry with its decade long planning process, high capital costs, and long term capital recovery periods survive in this type of energy market? Presuming that nuclear energy is still attractive in a fluctuating market, will reviving nuclear energy just delay the inevitable? If the nuclear power industry were expanded by one U.S. wedge, the U.S. would only have enough known uranium resources to last thirty-five to fifty-eight years.[246] However, this time frame could be extended should the U.S. adopt recycling, find new uranium sources, or expand the nuclear industry less than one wedge.[247] Still, these types of unanswered questions may negatively influence an investor's willingness to engage in nuclear ventures.

VII. SMART-GRID TECHNOLOGY

A. What is Smart-Grid?

Smart-Grid Technology is a package of technologies, some new and some dating back to the beginning of electrification, which seek to alter the traditional centralized grid system to make the electrical grid more secure, reliable, intelligent, distributed, and environmentally friendly.[248] The Energy Independence and Security Act of 2007 defines Smart-Grid technology as an advanced system that includes: (1) increased use of information controls; (2) optimization of grid operations and resources; (3) use of distributed resources and renewable energy; (4) development and integration of demand response, demand-side resources, energy-efficiency resources, smart appliances, advanced electricity storage, peak-shaving technologies,[249] smart metering, advanced communications, and distribution automation; (5) transfer of information to consumers

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246. LINDSEY GRANT, THE END OF FOSSIL FUELS: PART 1. HOW LONG THE TWILIGHT? (2004), *available at* http://www.npg.org/forum_series/fall04forum.html.

247. *See id.*

248. Patrick Meyer, *Industry Moving Forward with Smart Grid, Academia Stuck in 20th Century*, IEEE-USA, TODAY'S ENG'R, Oct. 2008, http://www.todaysengineer.org/2008/Oct/voice.asp.

249. Peak shaving involves boosting the natural gas (or other fuel) with additives to help stretch the fuel when prices are high. A popular shaving mixture contains seventy-five percent natural gas and twenty-five percent propane/air. Although peak shaving reduces costs, it can also increase pollution when used in a regular "manual fixed setting" type of plant. In order to prevent this increase in pollution, modern peak shaving technology requires a computer driven modification of the plant to make sure valve settings match the density of the fuel used. *See Atmosphere Maintenance Tips: Problems Caused by Peak Shaving*, METAL MINUTES HEAT PROCESSING NEWS, (SECO/WARWICK, Meadville, PA), http://www.secowarwick.com/metalminutes/maintenancetips/peakshaving.htm (last visited Mar. 19, 2010).

in a timely manner to allow for personalized control decisions; and (6) development of standards for the communication and interoperability of appliances and equipment connected to the electric grid.[250] Most Smart-Grid systems incorporate decentralized generating substations run by independent processors but linked into a "plug-and-play" type grid, much like the internet.[251]

The benefits of this type of system are diverse. By making the grid accessible, alternative and renewable fuel sources like wind turbines and solar power cells, which are more economical on smaller scales, can contribute to energy production.[252] Traditional power plants that produce heat as a by-product can use the heat for industrial purposes rather than discharging it into the atmosphere.[253] A more "intelligent" grid means access to information that can be used to increase efficient electrical use.[254] Smart meters give consumers up-to-the-minute electrical prices to help them make informed financial and conservation-related decisions while helping electrical generators make better decisions about when to generate more electricity and which fuel sources to use.[255] Additionally, a Smart-Grid system with smart meters would automatically identify a problem and "heal" itself in the event of an electrical outage, preventing blackouts and decreasing the number of electricians needed on the ground in a given area.[256]

Currently, conventional power plants generate electricity in large centralized facilities, transporting the energy long distances in order to take advantage of economical, geological, geographical, and human health benefits.[257] Today, many industrial and commercial buildings already use microturbines to generate electricity in the event of a power shortage.[258] Microturbines can come in the form of small-scale traditional

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250. Energy Independence and Sec. Act of 2007, Pub. L. No. 110–140 (2007).
251. *Id.*
252. FRED BOSSELMAN ET AL., ENERGY, ECONOMICS AND THE ENVIRONMENT: CASES AND MATERIALS 1067 (Foundation Press, 2nd ed. 2006).
253. *Id.* at 1066.
254. U.S. Dep't of Energy, Earth Day Animation Text Version, http://www.energy.gov/text_version.htm (last visited Mar. 19, 2010) [hereinafter DOE Earth Day]; *see also* General Elec. Co., Smart Meter Animation, http://ge.ecomagination.com/smartgrid/#/landing_page (last visited Mar. 19, 2010).
255. *Id.*
256. DOE Earth Day, *supra* note 254; General Elec. Co., *supra* note 254; DISTRIBUTED GENERATION EDUCATION MODULES, INTRODUCTION TO DG AND INTENTIONAL ISLANDING (2007), http://www.dg.history.vt.edu/ch3/islanding.html.
257. BOSSELMAN ET AL., *supra* note 252, at 1066.
258. *Id.*

reciprocating generators, fuel cells, photovoltaics,[259] micro-wind turbines, and other renewable generators.[260] This generating potential is rarely utilized because independent operators cannot "plug" into the grid, which causes them to choose either the centralized grid or their own back-up generators.[261] But in many cases, commercial buildings can use renewable energy sources and save money through the Smart-Grid system without losing the dependability of the supergrid.[262]

Smart-Grid technology would enable commercial, industrial, and other microturbine operators to generate their own electricity to use or store, lowering their electrical demand on the grid.[263] On-site generation prevents heat waste and lowers energy consumption.[264] If electric prices rise higher than the microturbine operators' cost of generating electricity, the operators could even sell their electricity over the grid, making a profit and reducing the overall cost of electricity.[265] Thus, distributed generation can help the electrical industry cope with the growing demand of the commercial sector and its associated growth in carbon emissions.[266]

B. Governmental Support for Smart-Grids & DER

Although Smart-Grids may seem futuristic, many Smart-Grids designed to utilize a variety of the aforementioned benefits are currently under construction across the United States.[267] Both the Energy Policy Act of 2005 and the American Recovery and Reinvestment Act of 2009 provided incentives for Smart-Grid technology. The Energy Policy Act of 2005 made energy tax credits available for businesses that operate microturbines and

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259. Photovoltaics refer to a field of semiconductor technology involving the direct conversion of electromagnetic radiation as sunlight, into electricity. Photovoltaics differ from traditional solar technology because they directly convert solar energy into an electrical current rather than into thermal energy. DICTIONARY.COM UNABRIDGED, http://dictionary1.classic.reference.com/browse/Photovoltaics (last visited Mar. 19, 2010).

260. CHRIS MARNAY, THE μGRID CONCEPT (2009) http://der.lbl.gov/new_site/DER.htm.

261. *Id.*

262. CHRIS MARNAY ET AL., MICROGRIDS FOR COMMERCIAL BUILDING. COMBINED HEAT AND POWER AND HETEROGENEOUS POWER QUALITY AND RELIABILITY 9 (2007), *available at* http://der.lbl.gov/new_site/pubs/LBNL-63520.pdf.

263. *Id.*

264. BOSSELMAN ET AL., *supra* note 252, at 1066.

265. *Id.* at 9–10.

266. *Id.*

267. Danny Bardbury, *Houston Prepares for $640m Smart Grid Blast Off: Project to Roll Out Smart Meters Capable of Providing Energy Use Data Four Times an Hour Moves Forward*, BUSINESSGREEN.COM, Feb. 4, 2009, *available at* http://www.businessgreen.com/business-green/news/2235724/texas-flick-switch-640m-sm.

other renewable energy sources.[268] The American Recovery and Reinvestment Act of 2009 allotted eleven billion dollars for Smart-Grid Technology, $6.3 billion for state and local governments to invest in energy efficiency, six million dollars in federal loan guarantees for renewable energy and electric transmission technologies, $4.5 billion for the Office of Electricity and Energy Reliability to modernize its grid as a Smart-Grid, $4.5 billion for state and federal government buildings to increase energy efficiency, $3.5 million for the Western Area Power Administration to upgrade its power transmission system, $2.5 billion for energy efficiency research, $3.2 billion for energy conservation grants, $300 million to buy energy efficient appliances, and $250 million to increase energy efficiency in low income housing.[269]

Smart-Grid technology is not just limited to the United States. Saudi Arabia is already building a series of co-generation plants throughout the Kingdom in order to reduce domestic drain on the national grid and preserve petroleum reserves for international trade.[270] The Saudis are also taking steps to interconnect the Saudi Arabian power grids with Kuwait, Bahrain, and Qatar by 2009.[271] The government of Ontario, Canada passed the *Energy Conservation Responsibility Act* in 2006 which requires the installation of smart meters on all Ontario businesses by 2010.[272] China will have its broadband enabled Smart-Grid running by 2012.[273] Similarly, the EU began working on its Smart-Grid in 2005 but doesn't expect to complete the grid until after 2020.[274]

Clearly, the current trend is supportive of Smart-Grid Technology, but is nuclear power incompatible with Smart-Grid? Nuclear power manages its high capital cost structure via economies of scale.[275] Whether or not nuclear power will thrive under a Smart-Grid infrastructure, however, is questionable.

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268. 26 U.S.C.S. § 48 (LexisNexis 2000); Energy Policy Act of 2005, Pub. L. No. 109–58, § 1336 (2005).

269. Am. Recovery and Reinvestment Act of 2009, Pub. L. No. 111–5, Title IV, 123 Stat. 115, 134–148 (2009).

270. ENERGY INFO., ADMIN., DEP'T OF ENERGY, COUNTRY ANALYSIS BRIEFS: SAUDI ARABIA 16 (2008), *available at* http://www.eia.doe.gov/emeu/cabs/Saudi_Arabia/pdf.pdf [hereinafter EIA, SAUDI ARABIA].

271. *Id.*

272. Energy Conservation Leadership Act of 2006, 3 S.O.

273. Alex Zheng, *China: The Next Big Smart Grid Revolution*, SMART GRID NEWS.COM, Aug. 1, 2007, http://www.smartgridnews.com/artman/publish/article_226.html.

274. EUROPEAN COMM'N, TOWARDS SMART POWER NETWORKS: LESSONS LEARNED FROM EUROPEAN RESEARCH FP5 PROJECTS 7 (2005), *available at* http://ec.europa.eu/research/energy/pdf/towards_smartpower_en.pdf.

275. *See* WHITFIELD, *supra* note 225.

Alternative renewable fuel technologies like photovoltaics and micro-wind turbines are more efficient when operated on a smaller scale. Thus, at the very least, alternative renewable fuel technologies will become more attractive as the Smart-Grid enables smaller plants to "plug in." Because many states now require the state energy portfolio to include the use of clean renewable fuels, (which usually exclude nuclear energy as a clean renewable fuel source) sizable incentives are available for these technologies from both the state and federal governments.[276] Assuming nuclear energy does become competitive under a carbon tax, it remains unclear whether or not nuclear energy could remain competitive as renewable technologies begin to gain access to local markets.

VIII. CONCLUSION

The United States is closer than ever to implementing a cap and trade system. Although the price of the carbon permits will have much to do with energy generation decisions, most electric generators will almost certainly move to natural gas as an alternative to coal-powered electrical plants in the short run. As natural gas becomes scarcer, high capital sources of low-emission energy generation like nuclear and wind power may become more attractive. Four effects might prevent or inhibit the spread of nuclear power as a wedge to reduce carbon emissions.

First, if cultural perceptions of nuclear risk have been adversely affected by early childhood education and pop culture, Americans may view any nuclear expansion as unduly risky—even if nuclear power is the most feasible and efficient way to reduce carbon emissions. Without public support, or at least public indifference, nuclear expansion may be impossible.

Second, trends in the U.S.'s nuclear waste disposal policy may inhibit nuclear expansion. Yucca Mountain is going nowhere fast and may already be at capacity if it is ever built. In the meantime, new nuclear power plants will have to plan on keeping all of their SNF on site, probably in dry cask storage yards. At a minimum, the problem with nuclear waste will cause extra disposal costs for nuclear generators. At worst, the NRC may not license any more nuclear power plants until there is a clear path for the permanent disposal of the new fleet's SNF.

Third, a marketable cap and trade system almost certainly means electric prices will significantly fluctuate over the next

276. PEW CTR. ON GLOBAL CLIMATE CHANGE, RENEWABLE AND ALTERNATIVE ENERGY PORTFOLIO STANDARDS 1, 2 (2009), http://www.pewclimate.org/sites/default/modules/usmap/pdf.php?file=5907.

fifty to sixty years, possibly in three distinct stages. Fluctuating prices could have a negative impact on investors' willingness to engage in nuclear ventures. Even more concerning, however, is that price fluctuations may predict a scenario where a sudden surge of interest in nuclear power plants would be followed by a series of systematic plant closings, similar to the 1980s, as nuclear power ceases to be competitive in the long run.

Finally, the advent of Smart-Grid technology may impede a nuclear power plant's ability to utilize the plant's economies of scale to recoup its high capital expenditures. Even if Smart-Grid has no direct effect on nuclear power, it will certainly make renewable energy sources such as wind power and photovoltaics more attractive as a competitor by enabling them to take advantage of their own mid-sized returns to scale.

Thus, although the arrival of a carbon cap and trade system has encouraged many debates about the potential role of nuclear power in reducing GHGs, decision makers should not be overly confident in the future of nuclear power. A complete resurrection of nuclear power may be as imprudent as allowing nuclear power to fizzle out too quickly. Indeed, the economic and environmental wellbeing of this country and the rest of the world will largely depend on the manner in which we approach modern energy policy decisions.