NUCLEAR FUTURES

JOSEPH P. TOMAIN†

INTRODUCTION

The *Duke Environmental Law & Policy Forum Symposium* "Environmental Regulation, Energy & Market Entry" is both important and timely and the editors are to be congratulated for this project. The *Symposium* is important, linking as it does energy and the environment and raising the question of how these two regulatory regimes affect our energy future. It has been the case for some time that energy lawyers and policymakers speak a language different than environmental lawyers and policymakers even though energy and the environment are of a whole.[1] Environmental impacts occur throughout all energy fuel cycles. Indeed, the consistent market imperfection in energy production, distribution, and use involves the negative externalities of pollution in its many forms.[2] Thus, a major point of convergence of energy and the environment concerns whether or not environmental regulations affect the market entry of various energy producers. In turn, the interaction of energy and the environment directly affects the shape of energy policy. Nevertheless, these two regulatory regimes tend to focus on and emphasize different elements.

The language of energy law and policy, for example, focuses on short term gains, economic efficiency, capital investment, return on investment, shareholder concerns and the like.[3] Energy industries, for

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† Dean Emeritus and the Wilbert & Helen Ziegler Professor of Law, University of Cincinnati College of Law; Scholar, Center for Progressive Regulation.

1. Current casebooks and textbooks on energy law and policy connect energy and environmental laws and policies and usually do so through economics. *See, e.g.*, FRED BOSSELMAN ET AL., ENERGY, ECONOMICS AND THE ENVIRONMENT (2000); ENERGY LAW GROUP, ENERGY LAW AND POLICY FOR THE 21ST CENTURY (2000); MARLA MANSFIELD, THE REEL WORLD: CASES AND MATERIALS ON RESOURCES, ENERGY AND ENVIRONMENTAL LAW (2001).

2. BOSSELMAN ET AL., *supra* note 1, at 41-47.

3. *See, e.g.*, Sam Kalen, *Replacing a National Energy Policy with a National Resource Policy*, 19 Nat. Resource & Envt'l 9 (2005); AMORY B. LOVINS, SOFT ENERGY PATHS: TOWARD A DURABLE PEACE 26-31 (1977).

the most part, are old, large, established, and politically influential.[4] In fact, the dominant model of energy policy in the United States consists of large-scale, capital intensive, and mostly fossil fuel industries.[5]

The language of the environment is distinct from that of energy. Resource preservation, conservation, stewardship, long-term protection and the like are the stock and trade variables of environmentalists.[6] To the extent that there is an alternative energy policy in the United States which relies on clean and renewable energy sources, its contribution to the production of energy has been minimal. For most of the last half century, alternative energy resources have never accounted for more than 3% of our energy economy.[7] To the extent that there are alternative energy producers, those producers tend to be small entrepreneurs who do not yet exercise significant political influence.[8] The significance and influence of alternative energy policies and alternative producers is changing, however, as a result of increased concerns about the harsh consequences of global warming and climate change.[9] Still, there exists a gap in our thinking and in our conversations about the relationships between energy and the environment, a gap reflected in policy and regulation. This *Symposium* presents an opportunity to discuss closing that gap by asking whether or not environmental regulations adversely affect energy markets.

The *Symposium* is timely because it comes at a critical period in the domestic and international conversation about the energy future. Over 30 years ago, the United Nations published a report urging governments to develop "sustainable societies" that would allow economic (and, therefore, energy) growth while protecting the environment.[10] Since that report, the United Nations has held two Earth

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4. *See* Cheney v. United States Dist. Ct., 124 S. Ct. 2576 (2004). The underlying complaint in that case was that the National Energy Policy Development Group, which wrote the Bush Administration's *National Energy Policy, infra* note 14, under the leadership of Vice President Cheney, was comprised of traditional energy industry representative such as Kenneth Lay of Enron and was devoid of environmental representation.

5. Joseph P. Tomain, *The Dominant Model of United States Energy Policy,* 61 U. COL. L. REV. 355 (1990).

6. *See, e.g.*, LOVINS, *supra* note 3, at 38-46; WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, OUR COMMON FUTURE (1987).

7. DOE ENERGY INFORMATION ADMINISTRATION, ANNUAL ENERGY REVIEW 276 (2003) [hereinafter *Annual Energy Review 2003*].

8. *See, e.g.*, VIJAY V. VAITHEESWARAN, POWER TO THE PEOPLE (2003); LOVINS, *supra* note 3, at ch. 1.

9. *See infra* notes 68-78 and accompanying text.

10. The concept of "sustainable development" was introduced at the United Nations Conference on the Human Environment in Stockholm in 1972. The idea was further developed in

Summits addressing sustainable development—one in Rio de Janeiro in 1992[11] and the second in Johannesburg in 2002.[12] Domestically, the National Energy Polices of the Clinton[13] and Bush[14] Administrations have paid lip service to the concept of sustainable development but nothing of note has come from those policies. Today, however, bipartisan thinking about energy and the environment is more visible. Shortly after this Symposium, for example, the William J. Clinton Presidential Foundation hosted a forum entitled *New Thinking on Energy Policy: Meeting the Challenges of Security, Development, and Climate Change.*[15] The Clinton Conference brought together international business and government leaders to discuss the global future of energy. The title of the conference captures the necessity of linking energy and the environment and, significantly, of linking both to matters of security. Two days later, on December 8, 2004, the Bipartisan National Commission on Energy Policy issued a major study entitled *Ending the Energy Stalemate*[16] which also emphasizes the intercon-

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UNITED NATIONS WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, OUR COMMON FUTURE (1987). This Report, also know as the "Brundtland Commission Report," after its Chair, Prime Minister Gro Brundtland of Norway, defined "sustainable development" as meeting the "needs of the present without compromising the ability of future generations to meet their own needs." *Id.* at 8.

11. For information about the Rio Earth Summit, see http://www.un.org/geninfo/bp/enviro.html (last visited Mar. 9, 2005).

12. For information on the Johannesburg Earth Summit, see http://www.earthsummit2002.org (last visited Mar. 9, 2005).

13. *See* PRESIDENT'S COUNCIL ON SUSTAINABLE DEVELOPMENT, SUSTAINABLE AMERICA: A NEW CONSENSUS FOR THE FUTURE (1996). *See also* U.S. DEPARTMENT OF ENERGY, NATIONAL ENERGY POLICY PLAN (July, 1995); U.S. DEPARTMENT OF ENERGY, STRATEGIC PLAN: PROVIDING AMERICA WITH ENERGY SECURITY, NATIONAL SECURITY, ENVIRONMENTAL QUALITY, SCIENCE LEADERSHIP (Sept. 1997); U.S. DEPARTMENT OF ENERGY, COMPREHENSIVE NATIONAL ENERGY STRATEGY (Apr. 1998).

14. NATIONAL ENERGY POLICY DEVELOPMENT GROUP, NATIONAL ENERGY POLICY ch. 3 (May 2001) [hereinafter *National Energy Policy*], *available at* http://www.whitehouse.gov/energy/National-Energy-Policy,pdf

15. A video of the Forum can be found at http://www.clintonfoundation.org/feature-energy-1206041.htm (last visited Mar. 4, 2005).

16. NATIONAL COMMISSION ON ENERGY POLICY, ENDING THE ENERGY STALEMATE: A BIPARTISAN STRATEGY TO MEET AMERICA'S ENERGY CHALLENGES (Dec. 2004) [hereinafter *National Commission Report*]. This Commission has been criticized by Public Citizen for being too industry oriented and not bipartisan enough; *see* http://www.citizen.org/pressroom/release.cfm?ID=1837 (Dec. 8, 2004). A year earlier, the Energy Future Coalition, another bipartisan group of energy leaders and thinkers published a similar report, ENERGY FUTURE COALITION, CHALLENGE AND OPPORTUNITY: CHARTING A NEW ENERGY FUTURE (June 2003) [hereinafter *Energy Future Coalition*], *available at* http://www.energyfuturecoalition.org/full_report/index.shtm.

nectedness of energy, the environment, the economy, and security at the national and international levels.

Clearly, recent events indicate a notable shift in thinking about energy policy, a shift that pays more attention to environmental impacts and geopolitical realities than before. My topic, nuclear power, is a central actor in this emerging drama. When first asked to participate in this *Symposium*, my initial response to the question "Do environmental regulations affect new market entry by nuclear power producers?" was — "No. Environmental regulations have no effect on new entrants because the nuclear power industry has been moribund for nearly three decades and market investments have simply dried up."[17] I could have very easily given the exact opposite answer and said: "Yes. Environmental regulations have completely precluded new nuclear power entrants because without an answer to the problem of nuclear waste disposal there will be no new nuclear plants coming on line."[18] Both statements are true.

Economics and environmental concerns affect the market entry of nuclear power. Curiously though, heightened concerns about climate change are beginning to renew interest in nuclear power. The Article proceeds to describe possible nuclear futures and discusses what is necessary for market entry for new nuclear plants. Part I places the nuclear power industry and its regulation in its historical context. This section will identify the core issues that surround the future of nuclear power. Part II engages in a thought experiment regarding the costs and benefits of nuclear power and its alternatives. This Part of the Article establishes the key variables necessary for an expansion of nuclear power. Part III presents three alternative nu-

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17. *See, e.g.*, PIETRO S. NIVOLA, THE POLITICAL ECONOMY OF NUCLEAR ENERGY IN THE UNITED STATES, BROOKINGS INSTITUTION POLICY BRIEF NO. 138 (2004) ("In America, it is safe to say, the halt [in the nuclear industry] has to do with basic economic considerations, not just political obstacles. . . . In the teeth of inauspicious market conditions, even the additional government intervention that was envisioned in last year's omnibus energy bill would not suffice to entice skeptical investors in the near term.").

18. *See National Commission Report, supra* note 16,at 58("Even with success in the cost and safety challenges, a new generation of nuclear reactors is unlikely to be built in the United States unless and until nuclear plant owners (largely electric utilities) and the public are persuaded that the government is able to meet its obligation, under existing law, to take possession of and adequately sequester the highly radioactive spent fuel from reactor operations."). *See also* JOHN DEUTCH & ERNEST J. MONIZ (CO-CHAIRS), THE FUTURE OF NUCLEAR POWER: AN INTERDISCIPLINARY MIT STUDY ix (2003) [hereinafter *MIT Study*]. The *MIT Study* argues that "high-level waste can safely be disposed of in geologic repositories . . . . We note, however, that among the general public, and even among some in the technical community, there is a lack of confidence in the prospects for successful technical and organizational implementation of the geologic disposal concept." *Id.* at 54.

clear power futures from which policy makers must choose. The Article concludes by suggesting what the immediate future holds in store for commercial nuclear energy.

I. THE SITUATION OF NUCLEAR POWER

A. *The State of the Industry*

The United States energy picture can be divided roughly between oil and electricity, each accounting for about 50 percent of the energy consumption in the country.[19] The electricity market can be divided again with coal accounting for 50 percent of electricity generation and nuclear power accounting for 20 percent, followed by natural gas at 18 percent with the remainder accounted for by all other resources including hydropower and other renewables.[20]

The commercial nuclear power industry began with a small 60 megawatt reactor at Shippingsport, Pennsylvania in 1957.[21] Today, there are 104 nuclear power plants in the country.[22] Those plants, however, have been operating for some time. No new nuclear power plants have come online since 1978 and all plants ordered since 1973 have been canceled.[23] Thus, it is more than fair to say that the nuclear power industry in this country has been moribund for 30 years after what promised to be a nearly inexhaustible and cheap source of energy.[24] A brief history of nuclear power and its regulation can highlight this dormancy.

B. *A Nano-History of Nuclear Power Regulation*

Our country, indeed the world, has always viewed nuclear power with fear and fascination. The very idea of fissionable atoms with their consequent release of large magnitudes of energy has been wrapped up with thoughts of both war and peace which continue to intrigue us.

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19. *Annual Energy Review 2003*, *supra* note 7, at 3.

20. *Id*. at 222.

21. BOSSELMAN ET AL., *supra* note 1, at 944.

22. MARK HOLT & CARL E. BEHRENS, CRS ISSUE BRIEF FOR CONGRESS: NUCLEAR ENERGY POLICY CRS-1 (Sept. 1, 2004).

23. *Id*.

24. The classic phrase, made by the first chair of the Atomic Energy Commission Lewis Strauss, was that nuclear power would generate electricity "too cheap to meter." *See infra* note 35 and accompanying text. *See also* STEVEN MARK COHN, TOO CHEAP TO METER: AN ECONOMIC AND PHILOSOPHICAL ANALYSIS OF THE NUCLEAR DREAM 107 (1997).

The story of atomic energy begins in earnest with the Manhattan Project in Los Alamos, New Mexico during World War II[25] under the direction of General Leslie Groves and Dr. J. Robert Oppenheimer. The Los Alamos project was the world's largest scientific undertaking to that time.[26] The first atomic bomb was exploded in Alamogordo, New Mexico at Trinity Site in 1945.[27] Upon seeing the mushroom cloud of radioactive energy after that first experimental explosion Oppenheimer commented: "Now I am become death, the destroyer of worlds," quoting the Bhagavad Gita.[28] After Alamogordo, the bombs were used to bring a conclusion to World War II with the destruction of Hiroshima and Nagasaka, Japan.[29] Oppenheimer's quotation strikes us as either odd or melodramatic given the fact that he was the lead scientist on the Manhattan Project and was fully knowledgeable about the task at hand. Nevertheless, it captures the fear and the fascination of nuclear energy that have gripped the world since its inception. The first use of atomic power for belligerent purposes is of renewed concern today.

After WWII, the future of atomic energy was a matter of international realpolitik. The United States was concerned that other countries, most particularly the then Soviet Union, would acquire nuclear weapons capacities. In order to maintain nuclear dominance, US government leaders believed that nuclear power had to be tightly controlled and did so through the Atomic Energy Act of 1946.[30] The 1946 Act established the Atomic Energy Commission, the predecessor agency to today's Nuclear Regulatory Commission, and invested all control of nuclear power in the hands of the military with no civilian involvement.[31] Such control only intensified the concern that atomic energy was to be used as the original weapon of mass destruction, yet nuclear power promised so much.[32] In particular, nuclear power could

25. Earlier, in 1942, the first successful fission experiment occurred at the University of Chicago. This experiment was a prelude to Los Alamos because the same scientists were involved in both projects. *See* RICHARD RHODES, THE MAKING OF THE ATOMIC BOMB 399-401 (1986).

26. *Id. See also* Miguel A. Bracchini, *The History and Ethics Behind the Manhattan Project* (Apr. 1997), *available at* http://www.me.utexas.edu/~uer/manhattan/.

27. RHODES, *supra* note 25, at 669-78.

28. *Id*. at 676.

29. *Id*. at 745 – 47.

30. Atomic Energy Act of 1946, Pub. L. No. 79-585, 60 Stat. 755 (1946).

31. *Id*.

32. *See, e.g.*, GEORGE T. MAZUZAN & J. SAMUEL WALKER, CONTROLLING THE ATOM: THE BEGINNINGS OF NUCLEAR REGULATION 1946 – 1962 ch. 1 (1984).

be used as a commercial energy source but the prevailing regulatory scheme under the Atomic Energy Act of 1946 precluded private ownership and commercial development.

In order to allay public concerns about nuclear power, President Eisenhower began advocating the "Atoms for Peace Program," most notably in a speech he gave at the United Nations in December, 1953.[33] Although the speech was benignly titled "Atoms for Peace," it concentrated on US concerns about weapons competition more than about the need to move nuclear power away from military uses to more peaceful uses. Also at that time, however, private industry was lobbying to bring nuclear power onto the commercial stage because of the great potential for profit. Industrial pressure for commercial use and international competition and concern about arms control contributed to the passage of the Atomic Energy Act of 1954.[34] The 1954 Act completely changed the way the country did its nuclear business, moving nuclear power into the hands of the private sector. The movement was captured by Atomic Energy Commission Chairman, Lewis Strauss, when he said that privatization was good for the country because electricity generated by nuclear power would be "too cheap to meter."[35] The 1954 Act is largely the regulatory structure which governs today. The Act promoted civilian ownership and commercial development and thus began the private commercial market.

There was, however, a significant market flaw in the nuclear power industry which constituted a complete impediment to commercialization. Simply, nuclear liabilities were too costly for any private entrepreneur to undertake, and the industry would not proceed without government support. Financial support came in the form of the Price-Anderson Act of 1957,[36] which limited the amount of liability a utility or reactor manufacturer would incur in the event of a nuclear accident.[37] During the Price-Anderson Act hearings, a representative of General Electric, one of the four key reactor manufacturers, said

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33. Dwight D. Eisenhower, *Address before the General Assembly of the United nations on Peaceful Uses of Atomic Energy*, *in* PUBLIC PAPERS OF THE PRESIDENTS OF THE UNITED STATES DWIGHT D. EISENHOWER, 1953 – 1960 813 – 822 (1960).

34. Atomic Energy Act of 1954, Pub. L. No. 83-703, 68 Stat. 919 (1954).

35. *See* JOSEPH P. TOMAIN, NUCLEAR POWER TRANSFORMATION 8 (1987); DANIEL FORD, THE CULT OF THE ATOM 50 (1982).

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

37. James R. Curtis et al., *Nuclear Power*, *in* 2 DAVID J. MUCHOW & WILLIAM A. MOGEL, ENERGY LAW & TRANSACTIONS §54.14 (2002)

that GE would not "proceed with a cloud of bankruptcy hanging over its head."[38] Similarly, Charles Weaver, the CEO of Westinghouse, another reactor manufacturer, said: "We knew at the time that all questions about 'safety and risk' weren't answered. That's why we fully supported the Price-Anderson Liability Legislation. When I testified before Congress, I made it perfectly clear that we could not proceed as a private company without that kind of government backing."[39] Commercialization was given the financial assurance it needed, and the Price-Anderson Act has continued to be reauthorized approximately every 10 years.[40]

The effect of the 1954 and 1957 legislation was quick and dramatic. Quite simply, utilities could not rush fast enough to order the construction of nuclear power plants to become part of what they imagined would be the electricity industry in the 21st Century. The period between 1957 through the mid 1960's was known as the Great Band Wagon Market for the commercial nuclear power industry.[41] Nuclear plants were the largest electric utilities operating until that time and continue to be so through the present. From 1963 to 1969, for example, the Atomic Energy Commission issued twenty-eight construction permits for plants ranging from 800 to 1100 megawatts which constitute the upper range of electric plant.[42] During this great construction period, nuclear generated electricity ultimately became one-fifth of all electricity production.[43] As active, optimistic, and aggressive as the Great Band Wagon Market was, the concert ended dramatically with the accident at Three Mile Island in 1979.[44] Depending upon how one reads history, Three Mile Island was either as close

38. TOMAIN, *supra* note 35, at 8 – 9.

39. *Id.* at 9.

40. Curtis et al., *supra* note 37, at §54.14[1] [c] & [d].

41. J. SAMUEL WALKER, CONTAINING THE ATOM: NUCLEAR REGULATION IN A CHANGING ENVIRONMENT, 1963-1971 ch. 2 (1992). *See also* MARK HERTSGAARD, NUCLEAR INC. 44 (1983).

42. WALKER, *supra* note 41, at 34.

43. *Annual Energy Review 2003*, *supra* note 7, at xxxii (describing nuclear power is equal to 20% of electricity produced).

44. *See* PRESIDENT'S COMMISSION ON THE ACCIDENT AT THREE MILE ISLAND, THE NEED FOR CHANGE: THE LEGACY OF TMI (1979) (also known as the Kemeny Commission Report). *See generally* J. SAMUEL WALKER, THREE MILE ISLAND: A NUCLEAR CRISIS IN HISTORICAL PERSPECTIVE (2004).

to a core meltdown as a reactor can get,[45] or a cautionary tale about the development of the industry.[46]

This brief history demonstrates two salient points about nuclear power. First, the private sector successfully galvanized significant political support and endorsement for generating electricity with nuclear power. This private sector interest coincided with national interests and both wanted US control and US market domination of nuclear power. The second and persistently troubling point about nuclear power is that it does not operate in a workable market. Financially, nuclear power does not function without government support. In the beginning, there would have been no Great Band Wagon Market without Price-Anderson protection.

After Three Mile Island, however, another gross market flaw reared its head. To that time, government policymakers had not paid sufficient attention to the back-end of the fuel cycle and had not regulated for permanent radioactive waste disposal. For it was not until 1982, with the passage of the Nuclear Waste Policy Act,[47] that the major environmental consequence of nuclear waste was addressed legislatively. Nuclear power, although carbon-free, is not free from environmental impact.

C. *The Nuclear Fuel Cycle and the Environment*

Commercial nuclear power can be divided into three stages—the front-end of the fuel cycle; the operational phase of the fuel cycle; and the back-end of the fuel cycle. There are environmental consequences at each stage and there are regulations to address those consequences.

The front-end of the fuel cycle involves the mining and milling of uranium as well uranium enrichment and fabrication. During the mining and milling phases, radiation hazards are low but are not nonexistent. Mill tailings, the remains of the mining process, contain radon which is environmentally hazardous and carcinogenic. These hazards are addressed in the Uranium Mill Tailings and Radioactive Control Act of 1978.[48] After the uranium ore is mined, it is then milled, which is the process of taking the ore and converting it into

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45. *See, e.g.,* DANIEL F. FORD, THREE MILE ISLAND: THIRTY MINUTES TO MELTDOWN (1982).

46. NUCLEAR ENERGY INSTITUTE, THE TMI 2 ACCIDENT: ITS IMPACT, ITS LESSONS (Mar. 2004), *available at* http://www.nei.org/doc.asp?catnum=3&catid=294.

47. 42 U.S.C. §§ 10101 – 10226 (2000).

48. 42 U.S.C. §§ 7901 – 42 (2000).

uranium oxide, a substance commonly referred to as "yellow cake."[49] The yellow cake is then converted into gaseous uranium hexafluoride, which allows for an enrichment process to raise the concentration of uranium from non-fissionable U_{238} to $U_{235,}$ which is a uranium enriched isotope capable of causing the necessary chain reaction.[50] Once the enrichment has taken place, the gas is returned to a solid state and fashioned into uranium pellets which are about the size of pencil erasers.[51] Those pellets are then fashioned into the fuel rods used in reactors to create nuclear fission.[52] The enrichment and fabrication phases create radioactive hazards that are also addressed by the Uranium Mill Tailings Act.[53]

The operational phase of the fuel cycle entails the use of the uranium produced by the front end of the cycle. Uranium has several uses, including hospital uses for x-rays, weapons production, and electricity generation. While hospital use generates low-level waste regulated by the Low-Level Radioactive Waste Policy Amendments Act of 1985,[54] this Article concentrates on electricity generation. Electric utilities must address a range of environmental matters including plant-siting, onsite waste disposal of spent fuel, and off-site waste disposal.[55] Plant siting can have environmental impacts on surrounding land and particularly water, which is used for cooling purposes. The cooling process draws water from nearby streams and returns warmer water to them, affecting fish and other aquatic life. This process and its effects are addressed in detail by federal regulations.[56]

The disposal of nuclear waste, however, is a larger problem. As noted above, the Nuclear Waste Policy Act of 1982 (NWPA) addresses permanent waste disposal.[57] The central problem with nuclear waste is that it is radioactive and, therefore, carcinogenic, and this radioactivity persists for thousands of years. The NWPA authorized a process to find a safe depository for permanent disposal; and the contentious site selection process concluded by identifying Yucca Mountain in Nevada as the final location, after numerous court challenges

49. WALKER, *supra* note 41, at 23.
50. *Id.*
51. *Id.*
52. *Id.*
53. 42 U.S.C. §§ 7914, 7918 (2000).
54. 42 U.S.C. §§2 021(b)-(j) (2000).
55. 10 C.F.R. pt. 51 (2004).
56. *Id*.
57. *See* Nuclear Waste Policy Act, *supra* note 47.

and Congressional interventions.[58] Yucca Mountain was scheduled to begin operation, but the most recent environmental challenge has prompted the D.C. Circuit to order a reconsideration of the safety of Yucca Mountain.[59] To date there is no place for final disposal of spent fuel. Instead, spent fuel is stored at the site of the nuclear reactor and those sites are given extended licenses until this matter is resolved.[60]

The back-end of the fuel cycle also evokes major environmental concerns, comprising on-site waste disposal, plant decommissioning[61] and license renewal.[62] The lack of a permanent disposal site is causing on-site waste disposal facilities to expand, and these expansions present environmental and safety concerns. The major environmental issue surrounding plant decommissioning is the radioactivity contained in the debris, and its transportation and disposal.[63] Furthermore, license renewals are occurring with greater frequency than expected. Once, it was contemplated that nuclear plants would operate for about 40 years.[64] Today, however, those estimates are being extended to 60 years[65] through license renewals in order to keep the plants operating.[66] Extended plant life raises safety and environmental concerns because of the longer lifespan of the plants. In short, the nuclear industry is affected by a wide range of environmental regulations that trace the full nuclear fuel cycle.

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58. *See generally* Ralph Ofierski, *Environmental Quality: Nuclear Waste Policy Act,* 22 ENVTL. L. 1145 (1992).

59. *See* Nuclear Energy Institute, Inc. v. EPA, 373 F.3d 1251, 1315 (D.C. Cir. 2004). The court ruled that the Environmental Protection Agency could not rely on an estimate of 10,000 years of safety because the Energy Policy Act of 1992 required the EPA to follow the recommendation of the National Academy of Sciences which recommended a 1-million-year estimate.

60. *See id.* (stating that currently, Yucca Mountain has not been approved as a waste disposal site).

61. US Nuclear Regulatory Commission, *Consolidated NMSS Decommissioning Guidance* NUREG-1757 (2003). *See also* 10 C. F. R. pts. 50.75, 50.82, 51.53 & 51.95 (2004).

62. US Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437 (1999).

63. *See, e.g.*, US Nuclear Regulatory Commission, *Decommissioning Nuclear Power Plants* (Jan. 2004) (decommissioning); 42 U.S.C. § 10175 (2000): 10 C.F. R. § 71 (2004) (transportation).

64. Union of Concerned Scientists, *U.S. Nuclear Plants in the 21st Century: The Risk of A Lifetime* 21 (May 2004).

65. *Id*. at 3.

66. *National Energy Policy*, *supra* note 14, at 5-17.

D. *Contemporary Concerns*

Brief descriptions of the nuclear power industry and its regulation reveal the key variables that affect nuclear policy past, present, and future. The fear of nuclear power has been that it can be used as a weapon of mass destruction with long-term consequences. After Three Mile Island, concern rose about the so-called China Syndrome, in which a reactor melts through the floor of the containment vessel and into the earth, figuratively finding its way to China with consequent releases of heat and radioactivity polluting air, water, and land.[67] Our fascination with nuclear power is the very idea that out of the atom can come massive amounts of energy that can be used not only for weapons but can be used to chill our beer, light our homes, and run our computers.

Today, anyone thinking about a nuclear future must consider the following:

- Will the public accept a renewal of nuclear power?[68]
- Are reactors safe after Three Mile Island?
- Is nuclear electricity cheaper than electricity generated by other sources?
- How will nuclear waste be disposed?
- How should we think about catastrophic incidents including weapons proliferation, climate change, and terrorist strikes at nuclear facilities?

In short, future nuclear policy must consider energy, the economy, the environment, and domestic and international security. The next section will put all those variables into a rough equation, but until each of those questions can be answered with some degree of comfort, there will be no commercial nuclear future.

II. FUNDAMENTAL CHOICE AND THE BIG COST-BENEFIT ANALYSIS

The future of nuclear power will depend on two inter-related decisions — one private and one public. At some point, private utility investors must decide whether or not to commit financial resources to nuclear power. Public policymakers, similarly, must decide whether to commit public resources to nuclear power. Recall that nuclear power

67. *See* J. SAMUEL WALKER, THREE MILE ISLAND 54 (2004).
68. *See MIT Study*, *supra* note 18, at ch. 9.

does not operate in a workably competitive market. Instead, the industry has always relied on government support. Without government, there would be no commercial nuclear power industry. Although these investment decisions are not identical,[69] both rely on rough calculations, and for illustrative purposes, I will set out the calculations in three equations.

At its most basic, the decision must made be as to whether or not the benefits of nuclear power outweigh its costs as depicted in Equation 1:

$$(1) \quad B > C$$

Essentially, policy makers and investors must decide that electricity generated from nuclear power will be less costly than electricity generated from other sources. We can use two fossil fuels, coal and natural gas, as comparative examples for this purpose.

In this regard, then, the first equation can be modified to show that a private investment decision (I) will be made when a megawatt of electricity from nuclear power (Mwh_N) is cheaper than a megawatt of electricity from fossil fuel power (Mwh_{FF}):

$$(1a) \quad I = Mwh_N < Mwh_{FF}$$

Next, investors must cost out a megawatt hour of electricity from both nuclear power and from fossil fuels. In this regard, the megawatt hour cost of nuclear power comprises: fuel costs (FC), construction costs (CC), operating costs (OC), waste disposal costs (WD), clean air costs (AC), global warming costs (GW), and other environmental costs (OE) such as environmental costs due to mill tailings, site preparation and degradation, water use effects on fish and aquatic life and the like. Thus, a megawatt hour of nuclear power can be represented in Equation 2:

$$(2) \quad Mwh_N = (FC + CC+ OC + WD + CA + GW + OE)_N$$

69. Private decision makers concentrate on return on investment and short-term gains for shareholders. Public decision makers should concentrate on the longer-term, public risk, safety and the cost of nuclear power. This broader focus, however, is not always the case. *See, e.g.*, David Lochbaum, *Nuclear Plant Risk Studies: Failing the Grade* 2 (Aug. 2000) (arguing that Nuclear Regulatory Commission risk assessments undervalue the potential consequences of nuclear accidents in their calculations.)

Similarly, a megawatt hour of fossil fuel power contains the same variables:

(2a) $Mwh_{FF} = (FC + CC + OC + WD + CA + GW + OE)_{FF}$

In the end, these two formulas must be compared. And, again, a private investment will be made in nuclear power when nuclear generated electricity is cheaper that fossil fuel generated electricity:

(2b) $Mwh_{N} = (FC + CC + OC + WD + CA + GW + OE)_{N} < Mwh_{FF} = (FC + CC + OC + WD + CA + GW + OE)_{FF}$

The difference between the costs of a megawatt hour of nuclear power and a megawatt hour of fossil fuel power can be considered the benefit side of the equation. As such, these equations look like a chain of simple additive variables. Yet, these cost equations are more algorithmic, given the complexity of some of the variables such as waste disposal and clean air costs. Nevertheless, deriving the cheaper price of electricity does not end even with those calculations because the cost side of the equation must be calculated as well. The variables become even more complex and greater uncertainties are introduced when total costs (TC) are examined. According to Judge Richard Posner:

> "Nuclear energy . . . is fully clean. But it is no panacea, because it is much costlier than power generation by plants that burn coal or natural gas, because of the difficulty of disposing of radioactive wastes, because of the danger of a catastrophic meltdown . . . because of the risk of terrorist's obtaining fissionable materials . . . and because of public fears . . ."[70]

Total costs, considered below in Equation 3, are especially important because public investments will be made only when the total cost of nuclear power is less than the total cost of fossil fuel power. Total costs include assessing the cost of catastrophic incidents (CI) surrounding nuclear power and there are three catastrophic incidents that must be considered. The first catastrophic incident is a core melt down or other reactor accident.[71] This is the type of safety issue in-

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70. RICHARD A. POSNER, CATASTROPHE: RISK AND RESPONSE 51-52 (2004)

71. *See* CONSTANCE PERIN, SHOULDERING RISK: THE CULTURE OF CONTROL IN THE NUCLEAR POWER INDUSTRY (2005).

volved with Three Mile Island. The second catastrophic incident is the risk of a terrorist attack on a nuclear installation.[72] The third incident concerns nuclear weapons proliferation and is more likely to involve the removal of uranium from a weapons facility rather than an electric utility.[73]

Such concerns about catastrophic incidents give pause to potential investors as well as to policymakers. These costs are part of the nuclear investment equation and the costs of a catastrophic incident must be discounted by the probability (P) that it will happen. Therefore, the total cost (TC) side of the equation is as follows:

$$(3) \quad TC = (CI_1 \text{ x } P) + (CI_2 \text{ x } P) + (CI_3 \text{ x } P)$$

Each catastrophic incident is comprised of fatalities (F), injuries (I), property damage (PD) and we can add psychological harms as well (Psy).[74]

$$(3a) \quad CI = F + I + PD + Psy$$

It thus remains, then, to calculate the probability of each catastrophic incident which leads us into the unknown. There is no reliable way to calculate the probability of a terrorist attack or of pilfered weapons grade uranium making its way into unfriendly hands.[75] Various probabilities have been estimated for reactor accidents as follows:

72. *See* GRAHAM ALLISON, NUCLEAR TERRORISM: THE ULTIMATE PREVENTABLE CATASTROPHE (2004).

73. *See, e.g.*, William J. Broad & David E. Sanger, *As Nuclear Secrets Emerge, More Are Suspect*, N.Y. TIMES, Dec. 26, 2004, at 1 (reporting the finding by US and International Atomic Energy Agency experts on the finding of blueprints for a 10-kiloton atomic bomb in the files of the Libyan weapons program.) The report also suspected that this information was the result of a deal made by a rogue nuclear weapons trafficker Dr. A.Q. Khan. *See id*. The story quotes an American expert as saying "[t]his was the first time we had ever seen a loose copy of a bomb design that clearly worked . . . and the question was: Who else had it? The Iranians? The Syrians? Al Qaeda?" *See id*.

74. The courts have not been overly solicitous of claims of psychological harms. *See* Metro. Edison Co. v. People Against Nuclear Energy, 460 U.S. 766 (1983) (holding that the NRC is not required to evaluate potential psychological impacts when evaluating environmental impacts of proposed nuclear site); Matthew D. Adler, *Fear Assessment: Cost-Benefit Analysis and the Pricing of Fear and Anxiety*, *available at* http://ssrn.com/abstract=466720 (Nov. 2004); Cass R. Sunstein, *The Laws of Fear,* 115 HARV. L. REV. 1119 (2002) (book review).

75. POSNER, *supra* note 70, at 174.

(3b) P = 1 :: 20,000 r/y
1 :: 10,000 r/y
1 :: 22 y

During the heyday of nuclear power, the Nuclear Regulatory Commission estimated that the chance of a core meltdown was 1 chance in 20,000 reactor years (r/y).[76] In other words, the NRC estimated that given 20,000 years of reactor life there was one possibility of a serious reactor accident. Since there are about 100 reactors then there is a chance that once in 200 years a reactor accident would occur. At the time, the Union of Concerned Scientists (UCS) criticized the NRC Reactor Study and estimated the chance of an accident at 1:10,000 or once in 100 years,[77] and UCS criticism continues to this day.[78] These probabilities can be compared with historic experience insofar as the Three Mile Island incident, a serious loss of coolant accident which could have led to a core meltdown, occurred just 22 years after the first commercial nuclear reactor was brought online in 1957. Estimating meltdown probabilities is, at bottom, a guessing game, but policymakers continue their modeling, with some growing historic experience to assist them.[79]

Once the probabilities are calculated, then the total costs of nuclear power and fossil fuel power must be compared:

(3c) $[(CI_1 \text{ x } P) + (CI_2 \text{ x } P) + (CI_3 \text{ x } P)]_N < [(CI_1 \text{ x } P) + (CI_2 \text{ x } P) +(CI_3 \text{ x } P)]_{FF}$

Or, more simply:

(3d) $TC_N < TC_{FF}$

76. US Nuclear Regulatory Commission, *Reactor Safety Study* WASH-1400 (Oct. 1975); *Severe Accident Risks*, NUREG-1150 (Dec. 1990); *Individual Plant Examination Program*, NUREG-1560 (Dec. 1997). These reports calculate risk as 5 events in 100,000 r/y which is the same as 1 event in 20,000 r/y.

77. UNION OF CONCERNED SCIENTISTS, THE RISKS OF NUCLEAR POWER REACTORS: A REVIEW OF THE NRC REACTOR SAFETY STUDY WASH -1400 (NUREG-75/014) 135 (1977) (on file with THE DUKE ENVIRONMENTAL LAW & POLICY FORUM).

78. Lochman, *supra* note 69, at 12.

79. *See MIT Study*, *supra* note 18, at ch. 6 (comparing probabilistic risk assessment with historic experience). *See also* US Nuclear Regulatory Commission, *Use of Risk In Nuclear Regulation*, at http://www.nrc.gov/what-we-do/regulatory/rulemaking/risk-informed.html (last updated Feb. 7, 2005)

This last equation brings up back to where we started. Investments will be made in nuclear power when B > C, or when the greater efficiency in electricity production outweighs the perceived risk of catastrophe. These equations are intended to be illustrative only and take the form of a rough cost-benefit analysis.[80] Hopefully, the point has been made that the nuclear future depends not only on private investment considerations of the sort that individual investors make all of the time. The nuclear future also depends on gross assumptions, rough estimates, and the valuation of imponderables as well as uncertainties affecting the public at large. Any nuclear future depends on such cost-benefit assessments made by public and private actors.

III. ALTERNATIVE FUTURES

Assessing the most likely future for nuclear power depends upon the question posed. An obvious, but incomplete, question is: "What is the future of nuclear power?" Answering this specific question leads to discussion of two alternative policies. The first alternative, the Promotional Nuclear Policy, is driven by concerns about climate change caused by fossil fuel emissions. This alternative emphasizes the use of nuclear power over coal to generate electricity. The second alternative, the Precautionary Nuclear Policy, focuses on safety including the disposal of radioactive wastes and the avoidance of the various nuclear catastrophes. This alternative emphasizes coal over nuclear power. Both alternatives accept the dominant model of energy policy with its reliance on large-scale, capital-intensive energy producers.

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80. Cost-benefit analysis is much more complicated and it is necessary to calculate a series of additional variables including the value of a life, as well as the discount rates to be applied on both sides of the equation among many others. There is a large literature dealing with the uses and abuses of cost-benefit analysis and I will refer the reader to some of the more prevalent scholarship. For a general introduction to the methodology see, E.J. MISHAN, COST-BENEFIT ANALYSIS: AN INFORMAL INTRODUCTION (3d ed. 1982); DAVID L. WEINER & AIDAN R. VINING, POLICY ANALYSIS: CONCEPTS AND PRACTICE (2d ed. 1992). For favorable scholarship toward cost-benefit analysis, see CASS R. SUNSTEIN, THE COST-BENEFIT STATE: THE FUTURE OF REGULATORY PROTECTION (2002); RISK AND REASON: SAFETY, LAW AND THE ENVIRONMENT (2002); COST-BENEFIT ANALYSIS: LEGAL, ECONOMIC, AND PHILOSOPHICAL PERSPECTIVES (Matthew D. Adler & Eric Posner eds., 2001) (largely favorable); POSNER, *supra* note 70. For critical scholarship, see BARUCH FISCHHOFF, THE ART OF COST-BENEFIT ANALYSIS (1977); Mark Sagoff, THE ECONOMY OF THE EARTH: PHILOSOPHY, LAW AND THE ENVIRONMENT (1988); Frank Ackerman & Lisa Heinzerling, PRICELESS: ON KNOWING THE PRICE OF EVERYTHING AND THE VALUE OF NOTHING (2004); Joseph P.Tomain. *Junk Economics,* 94 GEO. L. J. ___ (forthcoming 2005) (reviewing PRICELESS).

A differently posed question, such as: "What is the future of energy policy?" reveals a third alternative. This broader question challenges the dominant model and suggests that clean, renewable energy can play a larger role in the future that it does today and can provide an alternative to nuclear power. This third alternative is called the Smart Energy Policy.

A. *Promotional Nuclear Policy*

Support for nuclear power, at least according to industry[81] and occasional news stories,[82] has been on the increase, and that support has been recently fueled by two claims. First, nuclear power is an important alternative to carbon-based fuels, and second, nuclear power can become cost competitive with those fuels. These claims of environmental protection and low cost electricity must, however, withstand close scrutiny.

The core environmental idea behind the Promotion Policy is well stated in the *National Commission Report* which recommends that government policies "improve the prospects for the expansion of nuclear energy" because of society's interest "in abating climate-change risks by expanding the share of no-carbon and low-carbon energy options in the electricity-generating mix . . . ."[83] According to the *National Commission Report*, nuclear power accounts for nearly 70% of the non-carbon part of domestic electricity generation.[84]

This claim about environmental sensitivity enjoys international and industry support as well. The Nuclear Energy Agency, a department within the Organization for Economic Co-operation and Development (OECD), sees the potential of nuclear power as part of a sustainable development program which promotes both energy and economic development and environmental protection for both developed and developing countries.[85] Similarly, the nuclear industry has

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81. *See, e.g.*, Nuclear Energy Institute, *Energy Concerns Drive Record Public Favorability for Nuclear Energy* (June 2004).

82. *See, e.g.*, Thor Vladmanis, *Nuclear Power Slides Back Onto the Agenda*, USA TODAY, Sept. 27, 2004, at 1B; Alan Cowell, *Britain Feeling Pressure for Power*, N.Y. TIMES, Oct. 9, 2004, at B1.

83. *National Commission Report, supra* note 16, at 59.

84. *Id*. at 57.

85. *See, e.g.*, Nuclear Energy Agency, *Nuclear Energy in a Sustainable Development Perspective* (OECD 2000) *available at* http://www.nea.fr/html/ndd/docs/2000/nddsustdev.pdf (last visited March 4, 2005). Suffice it to say here that the concept is an expansive one and that in another version of sustainable development nuclear power may play no role. *See* Nuclear Energy Agency, *Nuclear Energy*

also asserted the compatibility of nuclear power with a cleaner environment through carbon-free electricity and emissions reductions.[86]

To the extent that the Promotional Nuclear Policy is premised on the need for non-carbon electricity generation, there is something odd about United States energy policy. Global warming or climate change is having a recognized impact on the world's weather with hotter summers, more tornados, melting Arctic and Antarctic regions and more additional meteorological effect.[87] More importantly, there is a scientific consensus that human, or anthropogenic, activity is a contributing factor to climate change.[88] Regardless, the Bush Administration has ignored the prevailing scientific consensus about the anthropogenic contribution to global warming,[89] has withdrawn the United States from any further participation in the Kyoto Protocol, and has

and the Kyoto Protocol (OECD 2002) (arguing he nuclear power can help meet the green house gas emissions goals of the Kyoto Protocol).

86. *See, e.g.*, Nuclear Energy Institute, *Powering the Future With Environmentally Sound Nuclear Energy: The Ecological Stewardship of the Nuclear Energy Industry* (2003) ("In 2000, the nuclear energy sector accounted for 43 percent of the carbon reductions reported nationwide." And, "Nuclear energy is by far the largest emission-free source of electricity in the United States, accounting for three-quarters of all clean-air electricity."). *See also* Nuclear Energy Institute, *Meeting our Clean Air Needs With Emission-Free Generation: The Need for Nuclear Power*, *available at* http://www.nei.org/documents/meetingneeds.pdf (last visited Mar. 9, 2005).

87. *See, e.g.*, Ross Gelbspan, THE HEAT IS ON 5 – 8 (1997); Ross Gelbspan, *Boiling Point* 19 – 22, 33 – 36, 63 – 66, 87 – 92, 119 – 126, 147 – 151, 171 – 174 (2004). *See also* Jim Motavalli (ed.), *Feeling the Heat: Dispatches from the Frontlines of Climate Change* (2004).)

88. The most notable organization in the world on global warming is the Intergovernmental Panel on Climate Change (IPCC). The IPCC is a joint effort of the World Meterological Organization and the United Nations Environment Programme and is open to all members of either organization. In its *Third Assessment Report*, the IPCC states clearly that "[c]oncentrations of atmospheric greenhouse gases and their radiative forcing have continued to increase as a result of human activities." *Summary for Policymakers: A Report of Working Group I of the Intergovernmental Panel on Climate Change* 7, *available at* http://www.ipcc.ch/pub/spm22-01.pdf (last visited Dec. 19, 2004).

89. *See, e.g.*, Larry Rohter, *U.S. Waters Down Global Commitment to Curb Greehnouse Gases*, N.Y. TIMES, Dec. 19, 2004, at 6 (reporting that the United States "blocked efforts to begin more substantive discussions" about reducing carbon emission pursuant to the Kyoto Protocol and "stood virtually alone in challenging the scientific assumptions underlying the Kyoto Protocol" of which the U.S. is not a part.). For other references regarding the Bush Administration's intransigence regarding the anthropogenic causes of global warming see Robert S. Devine, *Bush Versus the Environment* 174-79 (2004); Jim Motavalli (ed.), *Feeling the Heat: Dispatches From the Frontlines of Climate Change* 7-8 (2004); Carl Pope & Paul Rauber, *Strategic Ignorance: Why the Bush Administration is Recklessly Destroying a Century of Environmental Progress* ch. 10 (2004); Ross Gelbspan, *Boiling Point* 41-61 (2004).

instead initiated two clean coal programs,[90] neither of which have made any measurable contribution to emission reductions.

In addition to environmental protection, the Promotional Nuclear Policy claims that nuclear power is (or can become) cost competitive with fossil fuel electricity precisely because of the difficulties with fossil fuel emissions and, therefore, nuclear power should play a larger role in the future.[91] The Bush Administration's *National Energy Policy*, in this regard, argues that nuclear plants are safer, better operated, and cost competitive with other fuels.[92] These claims have some, but not complete, merit. The United States has experienced no nuclear incident of the magnitude of Three Mile Island since that event. Nevertheless, safety problems persist.[93] The *operating* cost of generating electricity from old nuclear plants is cost competitive with electricity from coal or natural gas but that is only because the construction costs have already been recouped in the rate base.[94] The real cost of new nuclear plants, which must account for construction costs, is not cost competitive with alternative fossil fuels.[95] There is also evidence that nuclear plants are becoming better managed, thus lowering costs, as managers gain in experience, and as utility consolidations concentrate that expertise.[96] At the same time, however, universities

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90. *The Clear Skies Initiative: Executive Summary available at* http://whitehouse.gov/news/releases/2002/02/print/clear-skies.html (Feb. 2002); *Global Climate Change Initiative*, *available at* http://whitehouse.gov/news/releases/2002/02/print/20020214.html (Feb. 2002). *See also* Department of Energy, *Clean Coal Power Initiative* (CCPI) *available at* http://www.fossil.energy.gov/programs/powersystems/cleancoal/ccpi/Prog052_4P.pdf (Sept. 2004); *Vision 21 Program Plan: Clean Energy Plants for the 21st Century* (Apr. 1999), *available at* http://fossil.energy.gov/programs/powersystems/vision21/index.html (last updated Nov. 30, 2004).

91. *See, e.g.*, David A. Repka & Kathryn M. Sutton, *The Revival of Nuclear Power Plant Licensing*, 19 NAT. RESOURCES & ENVT'L. 39 (2005).

92. *National Energy Policy, supra* note 14, at 5-15, 5-16.

93. *See e.g.*, John Sullivan, *Restarting a Reactor with a Flawed Part*, N.Y. TIMES, Dec. 12, 2004, at 33 (reporting the utility's desire to restart the Salem nuclear power plant in New Jersey in face of an internal engineering report that a critical pump's steel drive shaft was probably cracked and could cause an accident.)

94. *See* VAITHEESWARAN, *supra* note 8, at 280. Operating costs for nuclear plants are lower than those for coal and natural gas. ". . . America's nuclear plants cranked out power during the winter of 2000-2001 at an operating cost of just 1.8 cents per kilowatt-hour. Coal plants produced it for 2.1 cents per kW-hour, while those using natural gas . . . managed only 3.5 cents per kW-hour." *Id*.

95. Construction costs for nuclear power exceed those for coal and natural gas. *See* Scully Capital, *Business Case for New Nuclear Power Plants* (July 2002*) available at* http://www.scullycapital.com. *See also infra* note 100 and accompanying text.

96. *See, e.g.*, Jad Mouawad & Andrew Ross Sorkin, *Biggest Utility in New Jersey Seen as Target of Acquisition*, N.Y. TIMES, Dec. 18, 2004, at B1; Dennis K, Berman & John R.

are turning out fewer trained nuclear engineers to become those managers.[97] Still, the current *National Energy Policy* favors the promotion of nuclear power by increasing the power ratings of existing plants, continuing to re-license plants, continuing support for the Price-Anderson Act, and providing tax breaks for decommissioning.[98]

A recent study conducted at the University of Chicago regarding the future of nuclear power has been touted by the Department of Energy as demonstrating that nuclear power is cost competitive with coal and natural gas.[99] The University of Chicago Study[100] does not bear out that claim as it analyzes a future energy scenario which compares the cost of electricity among nuclear power, coal, and natural gas. The *Chicago Study* uses what it terms the "levelized cost of electricity" (LCOE) which includes operating and annualized capital costs. The LCOE is used to compare the cost of nuclear generated electricity with electricity generated by coal and natural gas. Despite the DOE headline, the *Chicago Study* reveals that without new promotional policies, nuclear power goes lacking.[101] The *Study* further notes that, even under the most favorable circumstances, nuclear power is more expensive than either coal or natural gas.[102]

In order to make nuclear power cost competitive with either coal or natural gas, government financial support is necessary. The *Chicago Study* argues that through a combination of government loan guarantees, accelerated depreciation, investment tax credits, and production tax credits, together with some aggressive assumptions about

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Emshwiller, *Exelon Discuses Deal With PSEG,* WALL ST. J., Dec. 20, 2004, at A3; Eric Dash, *Exelon Plans to Buy New Jersey Utility*, N.Y. TIMES, Dec. 21, 2004, at C2 (reporting the potential acquisition of New Jersey's largest utility P.S.E.&G. by the Exelon Corporation an owner of a number of electric utilites and an experienced manager of nuclear plants). *See also* VAITHEESWARAN, *supra* note 8, at 280.

97. VAITHEESWARAN, *supra* note 8, at 288.

98. National Energy Policy Development Group, *National Energy Policy* 5-15 to 5-17 (May 2001).

99. DOE Press Release, University of Chicago, *Nuclear Power Competitive with Coal & Natural Gas* (Sept. 20, 2004), *available at* http://www.doe.gov/engine/content.do?BT_CODE=PR_PRESSRELEASES&TT_CODE=PRESSRELEASE&PUBLIC_ID=16684.

100. University of Chicago, *The Economic Future of Nuclear Power* (Aug. 2004)[hereinafter *Chicago Study*].

101. *Id.* at 5-4.

102. *Id.* at 5-1 ("Given the capital cost range, the LCOE of new nuclear plants in the absence of policies is from $53 to $71 per MWh, with a 7-year construction time. The range is lower at $47 to $62 per MWh with a 5-year construction time. Costs remains outside the range of competitiveness with coal and gas, which have LCOE's of $33 to $41 per MHw and $35 to $45 per MWh respectively.").

construction and management, nuclear power can become cost competitive.[103] The necessary financial support is significant. Production tax credits alone could provide $6 billion to $19.5 billion to the nuclear industry.[104] These tax credits were proposed in the energy legislation that failed in Congress in 2003.[105] More specifically, in that legislation, nuclear plant operators would be given 1.8 cents per kilowatt hour of electricity generating capacity in new nuclear plants.[106] The *Chicago Study* concludes, however, by noting that "no single financial policy alone can definitely be counted on to bring about nuclear competitiveness by 2015."[107] Another form of financial incentive is, in effect, a reverse subsidy, through which a carbon tax is levied on fossil fuels for the purpose of making nuclear power cost competitive with coal and natural gas as those prices rise.[108] In addition to the financial incentives listed in the *Chicago Study*, the federal government has also been urged to assist the RDD&D — research, design, development, and demonstration — of new nuclear technologies such as advanced and standardized reactor designs at a suggested $2 billion over the next ten years.[109]

According to the *Chicago Study*, these financial incentives will only work if the construction period for new plants can be reduced to five years, a feat which has never yet been realized in the construction of nuclear power plants.[110] In addition, the *Study* argues that before nuclear power can be cost competitive, aggressive learning assumptions must be made.[111] In particular, the study states that nuclear power can be generated at $40 per Mwh with a 5-year construction

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103. *Id.* at ch. 5.

104. *See MIT Study, supra* note 18, at 81 (recommending a production tax credit that would result in a 200 million dollar subsidy per 1000 megawatt plant which amounts to about 2 billion dollars paid out over several years).

105. Energy Policy Act 2003, H.R. 6, 108th Cong (2003).

106. *See, e.g.*, Nuclear Information & Resource Service, *The Energy Bill HR 6: A Gift that Keeps on Taking*, *available at* http://www.nirs.org/factsheets/productiontaxcredits.htm (last visited Dec. 20, 2004).

107. *Chicago Study*, *supra* note 100, at 9-1.

108. *See, e.g.*, *MIT Study*, *supra* note 18, at 78.

109. *National Commission Report supra* note 16, at 60. *See also National Energy Policy*, *supra* note 14, at 5-17.

110. *Chicago Study*, *supra* note 100, at 5-1. *See generally* JOSEPH P. TOMAIN, NUCLEAR POWER TRANSFORMATION (1987).

111. The *Chicago* Study, *supra* note 100, also makes several financial assumptions about depreciation (§5.2.5); rates of return on equity (§5.3.3); rates of return on debt (§5.3.4); cost of capital (§5.4.2.2); and, risk premium (§5.4.2.3) all of which can have dramatic consequences on private investment decisions.

assumption only after the fifth standardized plant is built.[112] Cost reductions might also come from experience by reducing "first of a kind engineering" (FOAKE) costs and by reducing "learning by doing" costs. The *Chicago Study* goes on to note that "learning by doing will reduce costs beyond first plants. It will make a contribution but by itself is not sufficient to safely ensure self-sufficient competitiveness."[113] FOAKE and learning by doing costs can be reduced if the "regulatory environment is stable, if the nuclear plant construction industry is competitive, and if engineering teams and construction crews are kept more or less continuously employed."[114]

Regardless of the increase in Promotional Policy advocates, nuclear power will not reemerge as a new source of electricity production without government subsidies, aggressive assumptions about investments and construction, increased costs of generating electricity by fossil fuels, and advances in nuclear technologies.[115]

B. *Precautionary Nuclear Policy*

The simplest way to define the precautionary principle is "better safe than sorry."[116] Once regulators know that an "activity is likely to harm people or the environment, [the precautionary] principle requires regulators to assume there is no safe level of human or environmental exposure to a harmful activity in the absence of reasonable evidence that such a safe level exists."[117] Thus stated, the precautionary principle shifts the burden to the producers of the negative externalities of proving that harm is unlikely.[118] The precautionary principle is particularly pertinent to public policy questions with the

112. The *Chicago Study* recognizes that the five-year assumption is ambitious particularly considering that the Department of Energy bases its forecasting on a seven-year assumption, *Chicago Study supra* note 100, at 5-17, 5-18.

113. *Id*. at 9-2.

114. *Id*. at 4-24. The *Study* goes on to report that costs reductions are more reasonably assumed "if the number of units that can be built at a single site is limited, and construction across sites is discontinuous."

115. Internationally, the Chinese government is pursuing an aggressive nuclear construction program bringing on line two reactors a year between now and 2020. Even with such an aggressive construction program, nuclear power, which now accounts for 2% of China's electricity production, will only then account for 4% because of China's growing demand. *See* Howard W. French, *China Promotes Another Boom: Nuclear Power*, N.Y. TIMES, Jan. 15, 2005, at A1.

116. FRANK ACKERMAN & LISA HEINZERLING, PRICELESS: ON KNOWING THE PRICE OF EVERYTHING AND THE VALUE OF NOTHING 117 (2004).

117. A NEW PROGRESSIVE AGENDA FOR PUBLIC HEALTH AND THE ENVIRONMENT 31-32, 94-95 (Christopher H. Schroeder & Rena Steinzor eds., 2005).

118. *Id*. at 93-96.

potential for catastrophic consequences, even when a scientific consensus is lacking and probabilities of occurrence are low. The principle enjoys application in international environmental regulations[119] but has been subject to criticism in the United States.[120] The basis of the criticism is that "safe is not necessarily better than sorry," especially if efficiency and technological and scientific progress suffer.[121]

Policy analysts who argue against expansion of nuclear power use two arguments. The first argument is that nuclear power is simply not cost competitive with other fuels. The second argument is that safety and risk concerns still exist and, in fact, are of increasing concern given the rise of terrorism in the world.[122]

The Natural Resources Defense Counsel, by way of example, "neither expects nor supports a nuclear power revival."[123] The NRDC argues that nuclear plants are simply not cost competitive with other sources of electricity generation. According to their study, cleaner alternatives such as energy efficiency, wind, biomass, and solar power can be made operational sooner and more cheaply than nuclear power.[124] In addition, nuclear power is unattractive because of the risk of weapons proliferation, unsafe reactor design, a too favorable Price-Anderson Act subsidy, and because there is still no operationally safe, permanent waste depository.[125]

The Union of Concerned Scientists has for decades served as the watchdog group over matters of reactor safety. Not surprisingly then, their recent study concentrates on the safety features of nuclear power and concludes that "[b]y failing to consistently enforce the regulations, the NRC exposes millions of Americans to greater risk than necessary."[126] The UCS argues that one must not think about the safety of nuclear power plants in a linear way. Instead, safety assump-

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119. *See, e.g.*, ARIE TROUWBORST, EVOLUTION AND STATUS OF THE PRECAUTIONARY PRINCIPLE IN INTERNATIONAL LAW (2002); Rio Declaration on Environment and Development — Principle 15, *available at* http://www.unep.org/Documents/?DocumentID=78&ArticleID=1163 (last visited Mar. 9, 2005).

120. *See* Cass R. Sunstein, *Cost-Benefit Analysis and the Environment* 17-21 (Oct. 2004) (arguing that the precautionary principle is incoherent), *available at* http://www.law.uchicago.edu/ Lawecon/index.html; POSNER, *supra* note 70, at 139 – 150.

121. *See* CASS R. SUNSTEIN, RISK AND REASON 102-05 (2002).

122. *See generally* ALLISON, *supra* note 72.

123. Daniel Lashof & Patricio Silva, *A Responsible Energy Policy for the 21st Century* 18 (Mar. 2001).

124. *Id*. at 19.

125. *Id*. at 18 – 21.

126. David Lochbaum, *U.S. Nuclear Plants in the 21st Century: The Risk of a Lifetime* 2 (May 2004).

tions must be made along what they term a "bathtub curve."[127] By this term, the UCS means that risk starts high in the initial years of a plants life as they are coming online, abating for a period of time until the plant's become older, during which time safety concerns increase. In other words, for those advocates of nuclear power, their assertions that plants are enjoying good safety records is true along the low flat part of the bathtub curve, which is the part of the curve most plants are experiencing today.[128] Safety risks will increase, according to the study, as nuclear plants age.[129] The UCS then urges that NRC safety inspections must be increased, as must public participation in the relicensing process. They argue, further, that risk analyses for nuclear power are inadequate, and that if nuclear power is to be given a true market test, then Price-Anderson Act protection must be eliminated, at least for new plants. In other words, UCS takes the position that nuclear power cannot pass a market test and, therefore, further subsidies in the face of safety concerns are not warranted. The UCS then makes a series of recommendations, all aimed at improving NRC performance throughout the life cycle of a nuclear plant.[130]

The recent Massachusetts Institute of Technology study of the future of nuclear power is also cautious, arguing that nuclear power should be an option for reducing carbon emissions but at present "[T]his is unlikely: nuclear power faces stagnation and decline."[131] The *MIT Study* argues that for nuclear power expansion to succeed, several substantial hurdles must be cleared including:

- nuclear power must become cost competitive with coal or natural gas;
- carbon emission credits can help nuclear power;
- nuclear power must have improved safety through "best practices" in construction and operation;
- waste disposal issues must be satisfactory addressed;
- international safeguards against proliferation must be maintained; and,

127. *Id*. at ch. 1.
128. *Id*. at ch. 3.
129. *Id*. at ch 4.
130. *Id*. at 9 – 10,17 – 18, 21 – 22.
131. *MIT Study, supra* note 18, at ix.

- nuclear power generation must be limited to once-through fuel cycles rather than reprocessing.[132]

The Precautionary Policy, thus, is skeptical about the future of nuclear power. Nuclear does not appear to pass a market test, has increasing safety concerns, and does not have great promise for replacing fossil fuels. Presumably, if those hurdles are cleared, there can be a nuclear future.

C. *Smart Energy Policy*

The third policy alternative—the Smart Energy Policy—is distinguishable from the Promotional Policy and from the Precautionary Policy because the latter policies contemplate large-scale power producers and design their energy policies accordingly. The Smart Policy, to the contrary, articulates an energy future that does not rely on the dominant model, because that model is hazardous to our collective health and to the health of the environment.[133] Instead, the Smart Policy promotes small-scale, clean, renewable energy sources which are more environmentally friendly and less prone to catastrophic incidents.[134]

More than twenty-five years after publication of *Soft Energy Paths*, its author, Amory Lovins, is now being recognized as a serious thinker and contributor to our energy future by a wide and bipartisan group of energy policy actors.[135] In *Soft Energy Paths*, as well as in other publications, Lovins was clear about the utility of nuclear power—he saw little usefulness for it.[136] His great metaphor for nuclear generated electricity is that a nuclear power plant is nothing other than a large tea kettle, and heating water for that kettle with

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132. Reprocessing creates plutonium which is longer-lived, more dangerous, and more susceptible to weapons proliferation. This process is also know as a closed cycle and remains in disfavor across the board. *MIT Study, surpa* note 18, at ch. 4; *Chicago Study supra* note 100, at Appendix A5; ALLISION, dupra note 72, at ch. 7.

133. LOVINS, *supra* note 3, at chs. 1, 2, & 5.

134. *Id*.

135. Lovins has recently been referred to as the Sage of Snowmass by liberals and conservatives alike. *See, e.g.*, President Reagan's National Security Advisor Robert McFarlane, *A Declaration of Energy Independence*, Wall St. J., Dec. 20, 2004, at A15 (favorably reviewing Lovins book *Winning the Oil Endgame: Innovation for Profits, Jobs and Security*). See also http://www.oilendgame.org and VAITHEESWARAN, *supra* note 8, at 13-16.

136. *See, e.g.*, AMORY B. LOVINS & JOHN H. PRICE, NON-NUCLEAR FUTURES: THE CASE FOR AND ETHICAL ENERGY STRATEGY (1975).

nuclear power is "like cutting butter with a chain saw."[137] Lovins' analysis goes well beyond just staking out an anti-nuclear power position. His larger target is the dominant model of energy policy; His professional career has been dedicated to developing an alternative energy policy that relies on small-scale, clean, renewable energy production instead of large-scale, dirty, fossil-fuel energy.[138]

The No Nukes dimension of this alternative is straight forward but not terribly likely to come about in the near term because of the large role currently being played by nuclear power and our continued preference for large-scale power production. The active dimension of the Smart Policy involves technological innovation as well as restructuring the production and distribution of electricity.[139] A key aspect of this policy alternative involves distributed generation (DG), which presents an alternative electricity policy focusing on small-scale power production.[140] The core concept behind DG is that power will be produced locally instead of relying on large regional grids for transmission and distribution.[141] DG power producers will be much smaller and will rely on a variety of energy sources and technologies. What these producers have in common is that they are not traditionally structured utilities and can operate without reliance on the grid.

DG technologies include gas or diesel-fired engines, small turbines, fuel cells, and photovoltaic cells.[142] While some of these fuel sources are fossil fuels, it is contemplated that DG technologies will capture both heat and power, thereby increasing energy efficiency. Other fuel sources are renewable, and therefore cleaner than the fossil fuels burned in large-scale plants. Not all DG technologies are currently cost effective, thus raising the question of whether or not government financial incentives are better applied to nuclear power or to smart energy markets and technologies.

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137. LOVINS, *supra* note 3.

138. *See also* AMORY B. LOVINS ET ALS., SMALL IS PROFITABLE: THE HIDDEN BENEFITS OF MAKING ELECTRICAL RESOURCES THE RIGHT SIZE (2002)

139. *Id*.

140. The International Energy Agency defines "distributed generation" as 'generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distribution-level voltages. The technologies generally include engines, small (and micro) turbines, fuel cells, and photovoltaic systems. It generally excludes wind power, since that is mostly produced on wind farms rather than for on-site power requirement." International Energy Agency, *Distributed Generation in Liberalised Electricity Markets* 19 (2002).

141. *Id*.

142. LOVINS, *supra* note 138, at § 1.2.

Another term for distributed generation is micropower, which also involves new technologies including microturbines, hydrogen fuels, solar cells, landfill gases, and the like. In this regard, micropower is touted as a clean energy alternative. According to the International Energy Agency these technologies are increasing in importance and "[w]orldwide, more DG capacity was ordered in 2000 than for nuclear power."[143] Not too much should be taken from this statement because of the decrease in orders for new nuclear plants. Still, it is fair to assert a worldwide rise in DG and micropower.[144]

DG and micropower are dependent upon significant technological improvements in electricity production, transmission, distribution, and consumption. Most simply, the scale of generation units is reduced significantly and they are widely dispersed.[145] "Smart energy" technologies are intended to reduce the size of power generation units; to be closer to the source of consumption; to utilize "smart grids," which will transmit power more efficiently; and to use "smart meters," which will provide consumers with more information about their consumption patterns and about their choice of providers.[146]

The Smart Energy Policy is a return to the electricity future. When Edison flipped the switch at Pearl Street Station in New York City on September 4, 1882, the first electricity company went into operation and did so on a small scale.[147] Technological advances enabled the effective nationalization of the electricity grid in the early part of the Twentieth Century.[148] Today, we find ourselves contemplating a return to small scale production because it promises economic efficiencies by removing producers from the grid; environmental benefits through greater energy efficiencies and increased use of renewable energy resources; and energy security advantages from terrorist attack, international supply disruptions, or catastrophic accidents.

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143. International Energy Agency, *supra* note 140, at 7.

144. There is also an increase in the number of smart energy providers of information and products. *See, e.g.*, http://www.smartpower.org; http://www.smart-nrg.com; http://www.climatesolutions.org; http://www.elpc.org/energy/.

145. VAITHEESWARAN, *supra* note 8.

146. Energy Future Coalition, *Challenge and Opportunity: Charting a New EnergyFuture* Appendix A(4), *at* http://www.energyfuturecoalition.org/full_report/index.shtm (last visited Dec. 20, 2004).

147. LEONARD S. HYMAN, ANDREW S. HYMAN & ROBERT C. HYMAN, AMERICA'S ELECTRIC UTILITIES: PAST, PRESENT AND FUTURE ch. 14 (7th ed.2000).

148. JILL JONNES, EMPIRE OF LIGHT (2003).

CONCLUSION

Global warming has revived interest in nuclear power. How much interest remains to be seen. Still, the most significant statement that can be made about nuclear power is that this energy source is on the table for discussion more than it has been for over 25 years, because of the environmental degradation caused by burning fossil fuels.[149] Traditional nuclear industry and trade association interests have taken advantage of this phenomenon to continue to advocate their Promotional Policy regarding nuclear power. Nuclear agnostics have added this issue to their own future energy policies because it is an attractive alternative to oil and other fossil fuels, which, in addition to their role in climate change, are becoming more difficult to find and secure and, therefore, higher priced. Nevertheless, nuclear power's problems persist.

Economic efficiency, environmental protection, energy security, and potential catastrophes are the building blocks of any energy future. For some policymakers, nuclear power plays a central role in designing that future. If, however, a report card were issued for nuclear power, then chances are that nuclear power would not graduate to the energy policy of the immediate future. Instead, nuclear power would receive failing grades in each category.

Without government subsidies or financial incentives, nuclear power is not, nor is it projected to be, cost competitive with fossil fuels. While environmentally attractive because of its carbon-free emissions, the nuclear industry has not satisfactorily addressed waste disposal matters. Neither on-site expansion of spent storage facilities, nor permanent disposal at Yucca Mountain resolve the outstanding environmental issues yet. Nor does nuclear power achieve even passing grades on energy security and catastrophic incidents if future energy policy adopts a precautionary principle. A Precautionary Policy would force nuclear power providers to demonstrate the safety and security of their facilities and reactors; and that proof remains a challenge. Absent a precautionary principle, however, nuclear power would receive incomplete grades on both scores because of the magnitude of uncertainties.

What, then, is the future of nuclear power? The safest answer is "More of the same with a twist." Nuclear power will continue to pro-

149. *See, e.g.*, VAITHEESWARAN, *supra* note 8, at 278 ("What is fair to say is that after many years of ignoring nuclear power, policymakers are now starting to engage the issue once again.").

vide about 20% of the country's electricity needs. Old plants will be relicensed. On-site waste depositories will expand and Yucca Mountain will eventually receive approval as the permanent off-site waste storage facility. Price-Anderson Act support will continue, as will federal funds earmarked for nuclear RDD&D. The twist is that growing concerns about global climate change and national and international security have changed the terms of the debate about nuclear power's future. The changed debate raises a serious question about continuing to invest in nuclear power instead of investing in smart power.

A Smart Energy Policy provides a real alternative not only to nuclear power but also to the dominant model of national energy policy. There will be no new nuclear power in a Smart Energy Policy. Instead nuclear energy will play a transitional role. Cleaner and renewable energy resources will be used. Smaller, dispersed, energy efficient technologies are also a part of a Smart Energy Policy which sends more accurate price signals, increases consumer choice, and offers energy independence and security. The optimum nuclear future is then transitional, as we continue to use the nuclear power that we have, and as we begin to shift public and private investments into Smart Energy markets.