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The Ecological Advantages of Nuclear Power

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COLLOQUIUM ARTICLES

THE ECOLOGICAL ADVANTAGES OF NUCLEAR POWER

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TABLE OF CONTENTS

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INTRODUCTION

Will a new generation of nuclear plants be built in the United States? The United States is the world's largest supplier of commercial nuclear power. In 2005, there were 104 U.S. commercial nuclear generating units that were fully licensed to operate, and they provided about 20% of the Nation's electricity.[1] But no new nuclear plants have been built in the United States for over twenty years.[2]

Some policy makers and designers of such plants believe that they can now build plants that avoid the mistakes of the past and produce power that is both safe and economical.[3] Although Wall Street remains doubtful about the economics of such plants, the idea seems to be gaining momentum.[4] The Energy Policy Act of 2005 provided "Standby Support for Certain Nuclear Plant Delays," authorizing the Department of Energy to enter into up to six contracts with sponsors of new nuclear power plants under which the federal government will guarantee to pay certain costs incurred by the sponsors in case full power operation of the plant is delayed by litigation.[5] For individual projects, the Nuclear Regulatory Commission (NRC) has consolidated its permitting processes and established an Early Site Permit (ESP) program to resolve in advance all on-site environmental issues associated with the licensing of a new reactor.[6] Although no company has

[1] Energy Info. Admin., U.S. Dep't of Energy, U.S. Nuclear Generation of Electricity, http://www.eia.doe.gov/cneaf/nuclear/page/nuc_generation/gensum.html (last visited Feb. 3, 2007).

[2] DAVID BODANSKY, NUCLEAR ENERGY: PRINCIPLES, PRACTICES, AND PROSPECTS 34–35 (2d ed. 2004). For data on the construction of nuclear power plants in other countries, see INT'L ATOMIC ENERGY AGENCY, NUCLEAR POWER REACTORS IN THE WORLD (2006), *available at* http://www-pub.iaea.org/MTCD/publications/PDF/RDS2-25_web.pdf.

[3] *See* DENISE WARKENTIN-GLENN, ELECTRIC POWER INDUSTRY IN NONTECHNICAL LANGUAGE 40–42 (2d ed. 2006); *see generally* JOSEPH P. TOMAIN & RICHARD D. CUDAHY, ENERGY LAW IN A NUTSHELL 329–31 (2004) (noting that "[t]he Bush Department of Energy believes nuclear power to be safe, clean, and economical").

[4] A 2004 study by the Argonne National Laboratory, carried out in cooperation with the University of Chicago, concluded that new nuclear power plants could be economically competitive if the government provided investment and production tax credits. THE ECONOMIC FUTURE OF NUCLEAR POWER: A STUDY CONDUCTED AT THE UNIVERSITY OF CHICAGO 9-2 (2004).

[5] *See* Energy Policy Act of 2005, Pub. L. No. 109-58, § 638, 119 Stat. 594, 791–92 (2005) (to be codified at 42 U.S.C. § 16014); Standby Support for Certain Nuclear Plant Delays, 71 Fed. Reg. 46,306 (Aug. 11, 2006) (to be codified at 10 C.F.R. pt 950). For information on other federal support for nuclear power, see generally HELEN CALDICOTT, NUCLEAR POWER IS NOT THE ANSWER 26–37 (2006).

[6] *See* Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants, 10 C.F.R. § 52 (2005). For an analysis of these changes, see Neal H. Lewis, *Interpreting the Oracle: Licensing Modifications, Economics, Safety, Politics, and the Future of Nuclear Power in*

definitely committed to building a new plant, companies have filed applications for more than two dozen plants that are in various stages of the permit process.[7] The NRC must take into account various issues when deciding whether to allow these applications to go forward. Although Congress and the Administration have made their support for new nuclear power plants clear, any decision to build a nuclear power plant requires the agreement of many entities, including: (1) a company prepared to build it;[8] (2) financial backers willing to invest in it;[9] (3) federal policymakers and regulators;[10] (4) state energy and environmental regulators;[11] and (5) a local community prepared to site it.[12] These entities will undoubtedly take into consideration a wide range of issues, including safety, efficiency, profitability, health, and security.[13]

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the United States, 16 ALB. L. J. SCI. & TECH. 27 (2006).

[7] *See* Matthew L. Wald, *Slow Start for Revival of Reactors*, N.Y. TIMES, Aug. 22, 2006, at C1. For a map showing some of the potential sites for new nuclear power plants, see U.S. DEP'T OF ENERGY, NATIONAL ELECTRIC TRANSMISSION CONGESTION STUDY 58 fig.5-11 (2006).

[8] As of this writing, some companies appear to be eager to move forward, while others fear the financial risks involved. *See* Wald, *supra* note 7.

[9] *See* WILLIAM SWEET, KICKING THE CARBON HABIT: GLOBAL WARMING AND THE CASE FOR RENEWABLE AND NUCLEAR ENERGY 182 (2006); *see also* MASS. INST. OF TECH., THE FUTURE OF NUCLEAR POWER: AN INTERDISCIPLINARY MIT STUDY 37–38 (2003).

[10] Congress decides which types of energy to support, and the Nuclear Regulatory Commission, Department of Energy, Environmental Protection Agency, and Federal Energy Regulatory Commission all have jurisdiction relating to various aspects of nuclear power, the details of which are beyond the scope of this article.

[11] *See* FRED BOSSELMAN ET AL., ENERGY, ECONOMICS AND THE ENVIRONMENT 1117 (2d ed. 2006) (stating that state utility commissions susceptible to public pressure, i.e., consumer resistance, forced financial losses on utility shareholders during the construction of the first round of nuclear plants).

[12] Although local jurisdiction over safety and economic issues is preempted, local governments have a wide range of tools by which they can make life difficult for a plant they do not want. *See, e.g.*, Kerr-McGee Chem. Corp. v. City of W. Chicago, 914 F.2d 820 (7th Cir. 1990) (outlining a protracted battle between a local jurisdiction and a company operating a nuclear facility).

[13] *See* Joseph P. Tomain, *Nuclear Futures*, 15 DUKE ENVTL. L. & POL'Y F. 221, 237 (2005).

> [T]he 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.

This article concentrates only on one issue related to that decision—an issue that often receives less attention than it deserves: How will the decision affect ecological processes and systems, both in the United States and globally?[14] The article makes three arguments: (1) if nuclear power plants are not built, the gap will be filled by more coal-fired power plants; (2) the impact of coal-fired power plants on ecological processes and systems is likely to be increasingly disastrous; and (3) nuclear power's ecological impacts are likely to be neutral or even positive.

I. Coal and Nuclear Power Are the Realistic Choices to Meet the Need for Reliable Base-Load Electric Generation in the United States

Predicting the amount of demand for new electricity generation is difficult, but it is easy to predict that there will be at least some demand over the next decade.[15] In this section, I argue that: (A) electricity demand requires that electric utilities have access to several different types of power plants, including plants that can provide reliable "base-load" capacity; (B) even with dramatic improvements in energy conservation and efficiency, there will be a need for some substantial amount of new generating capacity; (C) generating plants powered by natural gas, wind, solar, or water will not be able to produce reliable base-load power within that time; and (D) no new technologies are likely to change these conclusions within the next decade. To meet the demand for base-load power, the choice is between coal and nuclear power.

A. *Electric Utilities Need Access to an Assortment of Different Types of Power Plants*

Electric utilities need to be able to have access to a "portfolio" of different types of generating plants. Because electricity cannot be stored on a large scale, power generators must continually

Id.

[14] In no way do I mean to imply that ecological issues should take precedence over other issues, but a discussion of all of the relevant issues would require a book, not a short article. Any evaluation of whether to proceed with a new generation of nuclear power plants must also address a host of other issues, including economics, diplomacy, security, and human health and safety.

[15] Except where otherwise indicated, reference to electricity demand and supply should be assumed to be related to the United States.

produce power as it is consumed.[16] Some users of electric power produce a relatively constant and predictable demand for electricity, and this amount is known as "base-load."[17] Electric utilities need reliable generation sources with low operating costs for meeting base-load needs.[18] Base-load power plants run virtually without interruption to supply the continuous portion of electricity needs, as compared to the needs that expand and contract seasonally or diurnally.[19] Base-load plants are often called "must-run" plants, because they will run for as long as possible at full load, and will produce the lowest overall power-generating costs for this type of use.[20] Today, many observers consider coal and nuclear power to be the only reliable future sources of base-load power.[21]

An electric utility's portfolio will also include different sources of power that meet other, equally important, needs. While base-load is fairly constant, electric utilities must be prepared for the times of the day and year when the demand for electricity increases. Generating plants that cycle on and off to address those variations are known as "intermediate load" plants.[22] They usually have a higher operating cost but can be started up and shut down

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[16] *See* VACLAV SMIL, ENERGY AT THE CROSSROADS 300 (2003).

[17] *See* WARKENTIN-GLENN, *supra* note 3, at 9–10.

[18] *See* U.S. Dep't of Energy, Energy Info. Admin., Glossary: B, http://www.eia.doe.gov/glossary/glossary_b.htm (definition of "Base-load plant") (last visited Feb. 9, 2007).

[19] *See id.*; GRANGER MORGAN ET AL., PEW CTR. ON GLOBAL CLIMATE CHANGE, THE U.S. ELECTRIC POWER SECTOR AND CLIMATE CHANGE MITIGATION 6, (2005), *available at* http://www.pewclimate.org/docUploads/Electricity_Final.pdf; *see also* WARKENTIN-GLENN, *supra* note 3, at 9–10; SWEET, *supra* note 9, at 182 (stating that nuclear power plants increasingly operate continuously except for planned shutdowns for refueling, operating 90.5% of the time in 2004).

[20] DAVE BARNETT & KIRK BJORNSGAARD, ELECTRIC POWER GENERATION: A NONTECHNICAL GUIDE 220–21 (2000).

[21] *See* Patrick Moore, *Going Nuclear: A Green Makes the Case*, WASH. POST, Apr. 16, 2006, at B1 (stating that wind and solar power are unpredictable, the price of natural gas is too volatile for it to be a reliable source of power, and that hydroelectric resources are already being used to capacity, leaving coal and nuclear power as the only reliable sources of base-load power); *see also* PAUL ROBERTS, THE END OF OIL 202–03 (2004) (stressing the preference for dependable power sources for base-load requirements, such as nuclear energy and coal); *see generally* NAT'L COAL COUNCIL, OPPORTUNITIES TO EXPEDITE THE CONSTRUCTION OF NEW COAL-BASED POWER PLANTS (2004) (advocating the continued and expanded use of coal power plants as a reliable power source).

[22] *See* WARKENTIN-GLENN, *supra* note 3, at 10.

relatively quickly.[23]

The third category of plants is "peak load" plants, saved for the times when seasonal weather changes or outages within the network make it essential to be able to start a generator almost instantaneously to meet peaks in demand. For these plants, starting speed takes precedence over operating cost.[24] These plants, typically burning natural gas, have high operating costs but can come off the bench and get up and running quickly.[25]

Another category of generation that is very cheap to operate once built, but can only operate under certain conditions, is the "variable must-run plants," because when the right conditions occur it is economical to use them to meet either base, intermediate or peak load needs. Because their availability is relatively unpredictable, they must be backed up by reliable generation sources. Hydroelectric, wind, and solar power plants are the primary examples.[26]

B. *Conservation Will Not Prevent the Need for New Power Generating Capacity*

Demand for electricity is influenced by many different factors, including the weather, the strength of the economy, the price of electricity, and the use of high-demand equipment and buildings. The history of the last fifty years has provided many examples of over- and under-estimation of demand growth, but no

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23 *See* MORGAN ET AL., *supra* note 19, at 6.

24 *See id.* at 6–7.

25 BARNETT & BJORNSGAARD, *supra* note 20, at 221; *see* MORGAN ET AL., *supra* note 19, at 7. For a chart illustrating peak, intermediate and base-load conditions, see MORGAN ET AL., *supra* note 19, at 7 fig.6. Small scale plants of this type can be built either by the consumer or the utility and are known as "distributed generation," but regardless of the size of these plants, they must run on one of the existing basic energy resources. Thus, for the reasons discussed in this section, they are likely to be used for peak-load purposes rather than for base-load purposes. *See id.* at 42.

26 *See* GILBERT M. MASTERS, RENEWABLE AND EFFICIENT ELECTRIC POWER SYSTEMS 144 (2004).

> The process of selecting which plants to operate at any given time is called *dispatching*. Since costs already incurred to build power plants (sunk costs) must be paid no matter what, it makes sense to dispatch plants in order of their operating costs, from lowest to highest. Renewables, with their intermittent operation but very low operating costs, should be dispatched first whenever they are available; so even though their capacity factors may be low, they are part of the baseload.

Id.

evidence of any decline in demand for any multi-year period.[27]

The hot summer of 2006 provided a test of the ability to make even short-run predictions of energy demand. California, having experienced severe shortages of electricity in 2000–2001, had instituted programs to cut back on demand and increase supply that decision makers thought equipped the state to face future hot summers, but the summer of 2006 forced various businesses to close at peak periods and severely strained the transmission network.[28]

Conservation programs to reduce electricity demand can be divided into two categories: (1) conservation programs that shift more electricity usage out of periods of peak usage and into times when demand is less (often called "peak-shaving"); and (2) efficiency-enhancing programs that reduce the total amount of electricity used, such as programs to require more efficient appliances or to mandate higher temperatures in air-conditioned buildings. Both types of demand management are being used in various places.

Insofar as the choice of the type of power plant to build is concerned, the peak-shaving programs and the efficient usage programs have differing effects on that decision. Both should reduce the overall amount of new generating capacity needed, but peak-shaving will result in an increase in base-load plants' share of overall generating capacity, because the usage removed from peak periods will be transferred to times when base-load plants are needed. Other efficient-usage programs may not have any major impact on the choice of the type of power plant to be constructed. Because Congress has mandated peak-shaving,[29] and many industries are eager to adopt it,[30] peak-shaving programs are likely

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[27] ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ANNUAL ENERGY REVIEW 2005, at 228 tbl.8.2a (2006), *available at* http://www.eia.doe.gov/emeu/aer/pdf/aer.pdf [hereinafter ANNUAL ENERGY REVIEW 2005].

[28] *See* Eugene Tong, *Power Demands Cripple DWP: Relentless Heat Puts Residents in the Dark*, DAILY NEWS L.A., July 24, 2006, at N1; Felicity Barringer, *California, Taking Big Gamble, Tries to Curb Greenhouse Gases*, N.Y. TIMES, Sept. 15, 2006, at A1.

[29] *See* Energy Policy Act of 2005, Pub. L. No. 109-58, § 1252, 119 Stat. 594, 963–67 (2005) (to be codified at 16 U.S.C. §§ 2621, 2622, 2625, 2642).

[30] The trade association of large electricity users, ELCON, supports the creation of peak-shaving opportunities. *See ELCON Advocates Demand Response*, ELCON REP., No. 2, at 2–3 (2006), *available at* http://www.elcon.org/Documents/ELCONReport/ELCONReport_2_2006.pdf.

to help tilt the choice of new facilities toward base-load plants.

California's efforts to encourage energy conservation focused on incentives for the more efficient use of electricity on a daily and yearly basis by smoothing out the demand for electricity and reducing peak needs.[31] These have succeeded in persuading some users of electrical equipment to shift from using it on hot summer afternoons, when demand for air conditioning is at its peak, to night time when demand is low, substantially reducing the ratio of peak to base-load demand.[32]

In the short run, much of this conservation will be created by the trend toward the use of "smart meters." A "smart meter" knows how much power you are using each hour of each day, and communicates the information back to the power company.[33] This makes it practical for an electric utility to charge higher rates for the use of electricity during peak hours, which in turn gives the customer an incentive to schedule the use of electricity at times of lower demand—an incentive that is lacking when meters register only gross monthly use.[34] The Energy Policy Act of 2005 requires all electric utilities to make time-of-use rates available to all customers by 2007.[35]

As electricity rates increase, the use of equipment that uses less electricity overall, not just at peak periods, will likely increase. When energy prices rose in the 1970s, an increased demand for such equipment was a definite factor in reducing the rate of increase in annual demand for electricity.[36] Even larger price increases might induce the government to impose mandatory requirements for more efficient refrigeration and air conditioning,

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[31] *See generally* ROBERTS, *supra* note 21, at 227–33 (describing California's conservation programs).

[32] *See* CAL. ENERGY COMM'N, OPTIONS FOR ENERGY EFFICIENCY IN EXISTING BUILDINGS, at v–vi, 17 (2005), *available at* http://www.energy.ca.gov/2005publications/CEC-400-2005-039/CEC-400-2005-039-CMF.PDF.

[33] *See, e.g.*, Chris King, *Demand-Response and Smart-Meter Provisions*, PUB. UTIL. FORT., Dec. 2005, at 60; Toronto Hydro-Electric System, Smart Meters—A Bright Idea, http://www.torontohydro.com/electricsystem/residential/smart_meter/index.cfm (last visited Feb. 9, 2007). For a picture of a smart meter, see http://www.power-technology.com/contractor_images/add/2_Meter.jpg.

[34] For an example of "time-of-use rates," see Toronto Hydro-Electric System, *supra* note 33.

[35] Energy Policy Act of 2005, Pub. L. No. 109-58, § 1252, 119 Stat. 594, 963–67 (2005) (to be codified at 16 U.S.C. §§ 2621, 2622, 2625, 2642).

[36] *See, e.g.*, ROBERTS, *supra* note 21, at 103.

but it is hard to envision such requirements having a major impact during the next decade, given the time needed to set standards, manufacture the equipment, and begin selling and using it. Within that period, energy efficiency regulation is likely to focus on the easier and quicker methods of reducing peak use.

Finally, even if demand for electricity stayed the same for the next decade, there would be a need for new generating plants. Tighter air pollution controls are scheduled to be phased in within that period, and the prospect of controls on greenhouse gas emissions will force plant owners to give more serious consideration to replacing aging plants with new ones.[37]

In sum, for the purposes of this article, I am not concerned with demonstrating how many new power plants will be needed, but only that some substantial number will be needed. Wall Street seems to agree because 159 new coal-fired generating plants are being proposed at various places in the United States.[38]

C. *Natural Gas Does Not Currently Appear to be a Viable Source of Base-Load Electrical Power*

Only a few years ago, the general consensus among the institutions that were building and financing energy facilities was that natural-gas-fired power plants would be the most efficient future source of all electrical power needs.[39] In the five-year period from 2000 through 2004, there was a sharp spike in construction of natural-gas-fired power plants.[40] Today, however,

[37] *See* Gary L. Hunt & George Given, *America's Resource Mix: Wind Gains, but Won't Soon Alter the Fuel Mix*, PUB. UTIL. FORT., July 2006, at 8, 8.

[38] NAT'L ENERGY TECH. LAB., U.S. DEP'T OF ENERGY, TRACKING NEW COAL-FIRED POWER PLANTS: COAL'S RESURGENCE IN ELECTRIC POWER GENERATION 3 (2007), http://www.netl.doe.gov/coal/refshelf/ncp.pdf. The early release version of the EIA's Annual Energy Outlook for 2007 forecasts a significantly increasing trend for the use of coal-fired generation in coming decades. *See* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ANNUAL ENERGY OUTLOOK 2007, EARLY RELEASE 4 (2007), *available at* http://www.eia.doe.gov/oiaf/aeo/pdf/earlyrelease.pdf.

[39] *See generally, e.g.*, BYRON SWIFT, ENVTL. LAW INST., CLEANER POWER: THE BENEFITS AND COSTS OF MOVING FROM COAL TO NATURAL GAS POWER GENERATION 16 (2d ed. 2001) (predicting that "reducing coal-fired generation by 50% by 2010" would lead to a "relatively smooth transition to natural gas power").

[40] For a graph that dramatically illustrates this construction binge, see *Impact of Clean Air Regulations on Natural Gas Prices: Hearing Before the S. Comm. on Clean Air, Climate Change and Nuclear Safety*, 109th Cong. 10 fig.2 (2006), *available at* http://www.eia.doe.gov/neic/speeches/howard020906.pdf

the future of natural-gas-fired plants seems cloudy for a number of reasons: (1) high prices; (2) doubts about future supplies; and (3) fears of future greenhouse gas controls.

1. *The Price of Natural Gas is High and Volatile*

As this is being written, the consensus of opinion has swung violently away from reliance on natural gas for base-load electricity generation.[41] The market price of natural gas increased sharply beginning in 2003 and has been highly volatile ever since.[42] As a result, many of the natural-gas-fired power plants that were built during the boom years have operated at a small fraction of their capacity and at much less than the anticipated profitability.[43]

Many of these plants were built in the expectation that

[hereinafter *Hearing*] (statement of Howard Gruenspecht, Deputy Administrator, Energy Information Administration, Department of Energy).

[41] Throughout the world, natural-gas-fired power is "no longer expected to be the most competitive option for baseload" power. INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2006, at 145 (2006) [hereinafter WORLD ENERGY OUTLOOK 2006]. "To enhance competitiveness and protect American jobs, natural gas must not be used for baseload electricity generation, nor for new generating capacity. . . . Nuclear energy must become the primary generator of baseload electricity, thereby relieving the pressure on natural gas prices and dramatically improving atmospheric emissions." MAJORITY STAFF OF H. COMM. ON GOV'T REFORM & H. SUBCOMM. ON ENERGY & RES., 109TH CONG., REPORT ON SECURING AMERICA'S ENERGY FUTURE 3 (2006).

[42] *See* ANNUAL ENERGY REVIEW 2005, *supra* note 27, at 196 fig.6.7, 197 tbl.6.7. The Energy Information Administration projects natural gas prices to remain in the $4.5 to $6 range for the foreseeable future. *See* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ANNUAL ENERGY OUTLOOK 2006 WITH PROJECTIONS TO 2030, at 87 fig.75 (2006), *available at* http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2006).pdf [hereinafter ANNUAL ENERGY OUTLOOK 2006]. But prices over $7 have been common in this highly volatile market. "Natural gas has soared 40% in the past two weeks, rallying from the second-lowest closing price this year after the hottest weather of the summer hit nationwide. Before the rally, gas had plunged 51% this year because of soaring inventories after mild winter and spring weather cut demand." Geoffery Smith, *Natural Gas Surges in New York on Hurricane Threat, Heat Wave*, BLOOMBERG NEWS, Aug. 2, 2006, http://www.bloomberg.com/apps/news?pid=20601087&sid=aQ7E3X2uT9FE&refer=home.

[43] *See* David Cay Johnston, *In Deregulation, Power Plants Turn into Blue Chips*, N.Y. TIMES, Oct. 23, 2006, at A1. The use of natural gas to generate electricity in 2004 was only about 40% higher than it was in 1995, despite the huge construction boom in natural-gas-fired power plants. ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ELECTRIC POWER ANNUAL 2005, at 13 tbl.1.1 (2006), *available at* http://www.eia.doe.gov/cneaf/electricity/epa/epa.pdf [hereinafter ELECTRIC POWER ANNUAL 2005].

electricity markets throughout the nation would be deregulated and interstate transmission at free market prices would be an everyday occurrence. In a deregulated market, the price of electricity would presumably rise to high levels in periods of peak demand, which would mean that a power plant could be profitable, even if it were only operated during peak periods.[44] However, after California deregulated its electricity market, the state experienced very high electricity prices and poor supply in 2000 and 2001.[45] "From May 22, 2000 until June 2001, the California electricity market was characterized by emergency alerts, rolling blackouts and huge price spikes."[46] "Electricity prices during the summer of 2000 had soared to unimaginable heights of $200, $400, $500, and even $800 per megawatt-hour (compared to a normal price of about $35 per megawatt-hour)."[47]

Companies that saw these prices quickly concluded that a natural-gas-fired power plant could be profitable even if it only operated on hot summer days, and the rush to build such plants was accelerated.[48] But the profitability of these plants depended not only on the assumption of a deregulated market for electricity, but on continuing stable prices of natural gas. For a variety of reasons, however, during this period the price for natural gas rose to unprecedented levels.[49] Support for deregulation waned, especially in the wake of the Enron bankruptcy.[50] Consequently,

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[44] *See* BOSSELMAN ET AL., *supra* note 11, at 528–30.

[45] *See id.* at 969–70.

[46] Jacqueline Lang Weaver, *Can Energy Markets Be Trusted? The Effect of the Rise and Fall of Enron on Energy Markets*, 4 HOUS. BUS. & TAX L.J. 1, 38 (2004).

[47] *Id.* at 48.

[48] "Between 1999 and 2005, over 230 gigawatts of new generating capacity was added and nearly all of it was primarily natural-gas-fired." *Hearing*, *supra* note 40, at 3.

[49] *Id.* at 2.

> Between 1990 and 1999, wellhead prices averaged $2.28 per mcf and remained below $2.64 each year during this period. . . . The average wellhead price in 2000 was $3.98 per mcf, 75% higher than the average price during the 1990s, and wellhead prices averaged $4.34 per mcf between 2000 and 2004. The average wellhead price in 2005 is estimated at $7.26 per mcf, more than three times the average price during the 1990s.

Id. For a natural-gas-fired power plant, the cost of the gas accounts for about 75% of the cost of the electricity produced. WORLD ENERGY OUTLOOK 2006, *supra* note 41, at 344.

[50] *See generally* Weaver, *supra* note 46.

many of the states that had begun to deregulate their electricity markets backed off, including California itself, leaving only a handful of states with truly open markets for electricity, and some of those are thinking about re-regulation.[51] In a regulated market, electricity prices are expected to lack big seasonal spikes.

Although retail electricity prices have risen in most states, they have tended to rise on a year-round basis.[52] The result has been that nuclear and coal-fired power plants, which have already recovered their capital investment and have much lower operating costs than the newer natural-gas-fired plants, have become profitable while many of the natural-gas-fired plants have been reduced to providing peaking power at rates that do not reflect market conditions.[53] This situation is likely to continue unless the price of natural gas drops back to 1990s levels.[54]

2. *Natural Gas Supplies Are Increasingly Unreliable*

Until recently, the United States obtained most of its natural gas from within the lower forty-eight states.[55] Gradually, supplies have been supplemented by imports from Canada, which now make up a significant part of the United States' supply.[56] In addition, we have begun to import relatively small amounts of natural gas in the form of liquefied natural gas (LNG), brought in by special tankers from countries such as Algeria and Trinidad to five LNG terminals located in various parts of the United States.[57]

Supplies of gas from domestic well fields have been

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[51] *See* KENNETH ROSE, 2004 PERFORMANCE REVIEW OF ELECTRIC MARKETS, at ii (2004), *available at* http://www.scc.virginia.gov/caseinfo/reports/2004_rose.pdf.

[52] *See also* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ELECTRIC POWER MONTHLY NOVEMBER 2006, at 3, 103–12 (2006), *available at* http://tonto.eia.doe.gov/ftproot/electricity/epm/02260611.pdf [hereinafter ELECTRIC POWER MONTHLY NOVEMBER].

[53] *See* MORGAN ET AL., *supra* note 19, at 17; *see also* Hunt & Given, *supra* note 37, at 9 (stating that existing nuclear "low-cost baseload capacity source[s have] proven to be enormously valuable and profitable").

[54] *See* MORGAN ET AL., *supra* note 19, at 17.

[55] *See* ANNUAL ENERGY REVIEW 2005, *supra* note 27, at 184 fig.6.1, 185 tbl.6.1.

[56] *See id.* at 189 tbl.6.3.

[57] *See* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, THE GLOBAL LIQUEFIED NATURAL GAS MARKET: STATUS AND OUTLOOK 23, 25–26 (2003), *available at* http://www.eia.doe.gov/oiaf/analysispaper/global/pdf/eia_0637.pdf [hereinafter LNG MARKET].

declining.[58] Production of gas from coal beds ("coalbed methane" or CBM) has helped, but the rapidly growing demand for natural gas has convinced the industry that our future supplies require new sources.[59] One potential source is the natural gas now being stored in the oil fields of Alaska's North Slope for lack of a pipeline.[60] In 2004, "Congress approved the Alaska Natural Gas Pipeline Act, which included an $18 billion loan guaranty, streamlined permitting, provisions for environmental review, . . . expedited court review" and other incentives.[61] In addition, the American Jobs Creation Act of 2004 provided seven-year tax depreciation for the pipeline and confirmed that an enhanced oil recovery credit applied to the gas processing facilities that will be associated with the pipeline.[62] This huge and expensive project is at least ten years from completion, if it will even be built.[63]

Therefore, substantially increased imports of LNG are projected for the foreseeable future.[64] Congress has streamlined the process of approval of new LNG terminals, and many such terminals are working their way through the process,[65] but these

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[58] BOSSELMAN ET AL., *supra* note 11, at 532.

[59] *See id.* at 634; ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, NATURAL GAS ANNUAL 2005, at 167 (2006), *available at* http://www.eia.doe.gov/pub/oil_gas/natural_gas/data_publications/natural_gas_annual/current/pdf/nga05.pdf. The development of CBM has had a significant adverse environmental impact. *See, e.g.*, Jerry Freilich, *Coalbed Methane Development Threatens Ranching, Crops, Streams & Wildlife*, WYO. OUTDOOR COUNCIL NEWSL., Summer 2002, http://www.wyomingoutdoorcouncil.org/news/newsletter/docs/2002c/cbmeffects.php.

[60] *See* Yereth Rosen, *Alaska Astir over Plan to Tap Its Big 'Tank' of Natural Gas*, CHRISTIAN SCI. MONITOR, Sept. 20, 2006, at 2; *see also* ROBERTS, *supra* note 21, at 182.

[61] *Report of the Legislation and Regulatory Reform Committee*, 26 ENERGY L.J. 253, 253 (2005); *see* Alaska Natural Gas Pipeline Act, Pub. L. No. 108-324, §§ 103, 104, 107(c), 116(c)(2), 118 Stat. 1255, 1256–58, 1261, 1266 (2004).

[62] American Jobs Creation Act of 2004, Pub. L. No. 108-357, §§ 706–707, 118 Stat. 1418, 1549–50 (2004).

[63] *See, e.g.*, Rosen, *supra* note 60.

[64] BOSSELMAN ET AL., *supra* note 11, at 634–37.

[65] *See* Maritime Transportation Security Act of 2002, Pub. L. No. 107-295 § 106, 116 Stat. 2064, 2068 (2002) (to be codified at 33 U.S.C. §§ 1501–1507); Richard J. Pierce, Jr., *Environmental Regulation, Energy, and Market Entry*, 15 DUKE ENVTL. L. & POL'Y F. 167, 175–76 (2005). For examples of 2006 Federal Energy Regulatory Commission decisions giving preliminary or final approval to new facilities for the importation of LNG, see Sabine Pass LNG, L.P., 115 F.E.R.C. ¶ 61,330 (2006); Creole Trail LNG, L.P., 115 FERC ¶ 61,331 (2006); Port Arthur LNG, L.P., 115 FERC ¶ 61,344 (2006); Freeport LNG Dev., L.P., 116 FERC ¶ 61,290 (2006); N. Baja Pipeline, LLC, 117 FERC ¶ 61,022 (2006).

terminals will need to rely on the ability to import natural gas from a wide range of countries at prices compatible with the market for domestic gas.[66]

At present, there are substantial amounts of "stranded gas" in foreign countries that are available at relatively favorable prices because they are located far from large markets,[67] but the worldwide demand for LNG is increasing and may grow even more rapidly if China and India begin to import LNG on a large scale.[68] In addition, some Persian Gulf nations with very large gas supplies are using gas-to-liquids technology to convert natural gas into diesel fuel, for which prices are now very favorable to sellers.[69] All of these factors make the future price and supply of natural gas much less predictable than ever before.[70]

3. *Natural Gas Combustion Emits Greenhouse Gases That May Be Subject to Increased Controls*

Natural gas is primarily methane mixed with smaller amounts of other hydrocarbons.[71] When hydrocarbons are burned, carbon dioxide is emitted into the air; carbon dioxide is the most prevalent of the "greenhouse gases," which have the effect of trapping heat in the Earth's atmosphere.[72] Methane itself is a greenhouse gas.[73]

For a summary of the status of the many North American LNG project proposals as of the summer of 2006, see Warren R. True, *North American LNG Terminals—1: East Coast Terminal Projects Buck Resistance, Move Ahead*, OIL & GAS J., Aug. 28, 2006, at 48; Warren R. True, *North American LNG Terminals—Conclusion: Gulf Coast Picture Clearing; Mexico Getting First Terminal*, OIL & GAS J., Sept. 4, 2006, at 85. It is widely assumed in the industry that a relatively small percentage of the proposed terminals will actually be built. *See* Gary Polakovic, *Big Baja Natural Gas Plant May Cool Rivals' Chances*, L.A. TIMES, Oct. 9, 2006, at B1.

[66] *See* BOSSELMAN ET AL., *supra* note 11, at 635–37.

[67] *See id.* at 641.

[68] *See* Monika Ehrman, *Competition Is a Sin: An Evaluation of the Formation and Effects of a Natural Gas OPEC*, 27 ENERGY L.J. 175, 181–83 (2006).

[69] *See* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, DIESEL FUEL PRICES (2006), *available at* http://www.eia.doe.gov/bookshelf/brochures/diesel/dieselprices2006.pdf; *see also* Tom Nicholls, *Alternative Fuels: Diesel Beats Gasoline*, PETROLEUM ECON., July 2006, at 7, 8.

[70] *See* LNG MARKET, *supra* note 57, at 36.

[71] *See* U.S. Dep't of Energy, Energy Info. Admin., Glossary: N, http://www.eia.doe.gov/glossary/glossary_n.htm (definition of "Natural gas") (last visited Jan. 11, 2007).

[72] *See* EPA, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2004, at ES-4 fig.ES-1 (2006), *available at* http://epa.gov/climatechange/

The gradually increasing emission of such gases has begun to affect the global climate to a significant degree,[74] and most scientists believe that such effects are likely to accelerate unless greenhouse gas emissions are controlled.[75]

Natural gas has an advantage over coal in that the amount of carbon dioxide produced by natural gas combustion is roughly one-half of the amount produced by the combustion of an amount of coal creating an equivalent amount of energy.[76] Nevertheless, the combustion of natural gas for electricity generation is providing a significant share of the nation's total carbon dioxide emissions.[77]

The bottom line is that many financial institutions today expect the government to create economic disincentives to the emission of greenhouse gases within the lifetime of any new capital project, reducing the expected profitability of any facility that omits greenhouse gases. Although any calculation of the amount of such disincentives would be speculative, a prudent investor would take the possibility of these costs into account in

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emissions/downloads06/06_Complete_Report.pdf [hereinafter INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS]; EPA, Global Warming—Emissions, http://yosemite.epa.gov/OAR/globalwarming.nsf/content/Emissions.html (last visited Feb. 9, 2007) (discussing the relative strength of various GHGs).

[73] *See* INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS, *supra* note 72, at ES-2. The escape of methane into the atmosphere during gas drilling is another way in which the use of natural gas contributes to climate change. ROGER G. BARRY & RICHARD J. CHORLEY, ATMOSPHERE, WEATHER AND CLIMATE 9 tbl.1.4 (7th ed. 1998). Fortunately, methane's residence time in the atmosphere is shorter than that of carbon dioxide. JAMES LOVELOCK, THE REVENGE OF GAIA: EARTH'S CLIMATE IN CRISIS AND THE FATE OF HUMANITY 74–75 (2006).

[74] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 2–9 (2007). The nature of the ecological impact of these emissions is discussed *infra*, Part II.A, in relation to coal. For purposes of the argument that natural gas is unlikely to be a strong competitor for base-load power generation, however, the nature of the effects of the emissions are irrelevant; what is important is the perception that such emissions will become more expensive, thus reducing the potential profitability of future investments in natural-gas-fired power plants.

[75] *See id.* at 10–21. Whether these predictions prove to be correct is not relevant to my argument. It is the prevailing *fear* that they will be correct that is important in influencing energy policy decisions affecting the next decade.

[76] *See, e.g.*, ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, INTERNATIONAL ENERGY OUTLOOK 2006, at 76 tbl.14 (2006), *available at* http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2006).pdf.

[77] ANNUAL ENERGY OUTLOOK 2006, *supra* note 42, at 103–04.

considering the long term profitability of long-range projects.[78]

In summary, the high price of gas, the uncertainty of the supply and price of future imports, and the fear of financial disincentives to greenhouse gas emission have brought the production of new natural-gas-fired power plants in the United States to a virtual halt. There may still be a place for more plants to meet peak needs in certain areas, particularly for small plants near sources of high demand, but the construction of new natural-gas-fired plants for base-load power generation seems quite unlikely at this time.[79]

D. *Renewables Can Play a Valuable but Limited Role*

The goal of a completely renewable system of electric generation appeals to almost anyone who does not have vested interests in the continued use of non-renewable energy sources. The currently available renewable sources of electrical energy on a large scale are primarily hydroelectric power (hydro),[80] wind,[81] and solar.[82] The United States and individual states have provided some incentives for the creation of renewable generating systems, and some European countries have provided even more,[83] but renewable energy resources can meet only a small fraction of reliable base-load electricity needs within the next decade because: (1) their availability depends on external factors beyond human control, requiring backup by reliable generation; (2) their potential location is also dependent on factors beyond our control; and (3)

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[78] Utilities and their underwriters are beginning to think seriously about how future greenhouse gas restrictions will affect energy plans. *See* Michael T. Burr, *Facing the Climate Challenge*, PUB. UTIL. FORT., Aug. 2006, at 52, 53; *see, e.g.*, Rebecca Smith, *Burning Debate: As Emission Restrictions Loom, Texas Utility Bets Big on Coal*, WALL ST. J., July 21, 2006, at A1.

[79] *See Hearing*, *supra* note 40, at 6–7; Henry Linden, *Coal No More: What If?*, PUB. UTIL. FORT., Sept. 2006, at 62, 62–66.

[80] Forecasts for climate change suggest that the ability to utilize hydro in western states will decrease because early snowmelt will overwhelm water storage capacity. T.P. Barnett et al., *Potential Impacts of a Warming Climate on Water Availability in Snow-Dominated Regions*, 438 NATURE 303, 305 (2005).

[81] Wind farms are being built using short-range government subsidies that allow developers to make quick profits without worrying very much about the long run. MARQ DE VILLIERS, WINDSWEPT: THE STORY OF WIND AND WEATHER 272–73 (2006).

[82] *See* SWEET, *supra* note 9, at 152–58.

[83] *See* Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594 (2005); ANNUAL ENERGY OUTLOOK 2006, *supra* note 42, at 24–25; SWEET, *supra* note 9, at 152–54.

new renewable technologies, although promising, are more than ten years away from large scale production.

1. *Renewables Must Be Backed up by Reliable Generation*

Existing renewables are not reliably dispatchable,[84] so they must be backed up by reliable sources that can be counted on to meet base-load needs.[85] For solar and wind energy, the reasons for their lack of reliability are obvious: the sun never shines at night, and does not always shine during the day, while wind's speed and consistency is highly variable in almost all locations.[86]

Although windmills have been used on a small scale for millennia, the modern technology for building aggregations of dozens or hundreds of wind turbines is relatively recent.[87] As the scale of the equipment has grown, developers are now producing wind turbines on towers many hundreds of feet tall.[88] The long-term reliability of this kind of equipment has never been tested.[89] The fact that government subsidies in the U.S. make it possible for

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[84] *See* MASTERS, *supra* note 26, at 144.

[85] *See* LOVELOCK, *supra* note 73, at 83. Some analysts argue that the right mix of renewables can become a relatively reliable source. *See* SWEET, *supra* note 9, at 155 (suggesting that three times as much wind or solar power would be needed to replace the power generated by reliable sources); Bob Fesmire, *Wind & Hydro: A Match Made in Heaven?*, ELECTRIC LIGHT & POWER, May–June 2006, at 26 (arguing that a combination of wind power and hydro power eliminates the inherent variability problems of either form of power alone); Lena M. Hansen, Note, *Can Wind Be a "Firm" Resource? A North Carolina Case Study*, 15 DUKE ENVTL. L. & POL'Y F. 341, 344, 381 (2005) (arguing that harnessing wind in different geographic areas can reduce the overall risk of wind power).

[86] *See* SWEET, *supra* note 9, at 154–56. *See generally* R. Dobie Langenkamp, *Sustainable Development—Renewable Energy and Reality*, *in* ENERGY, ECONOMICS AND THE ENVIRONMENT, *supra* note 11, at 1023 (describing the disadvantages of wind power). In very hot dry climates, solar power may be particularly appropriate for peaking purposes because its peak period of daily availability matches the times of day when air conditioning is being most heavily used. TRAVIS BRADFORD, SOLAR REVOLUTION: THE ECONOMIC TRANSFORMATION OF THE GLOBAL ENERGY INDUSTRY 128–30 (2006).

[87] *See generally* DE VILLIERS, *supra* note 81, at 233–81 (explaining history of human use of wind).

[88] *See id.* at 259; Langenkamp, *supra* note 86, at 1025.

[89] "First-generation megawatt-scale turbines have suffered a raft of costly gearbox failures, and the durability of the latest multi-megawatt turbines has not been tested over a 20- or 30-year life span." Michael T. Burr, *In the Mainstream, Wind Turbines Take Off*, PUB. UTIL. FORT., June 2006, at 87. Some of the early windfarms, such as California's famous Altamont Pass facility, are seriously deteriorating. *See* DE VILLIERS, *supra* note 81, at 269.

investors in windfarms to cash out their investment quickly also reduce the developers' incentive to emphasize long-range reliability.[90] Federal subsidies for windpower were extended in the Energy Policy Act of 2005.[91]

The unreliability of hydroelectric power is slightly less obvious, but equally important. Hydro is created when water in a reservoir flows through tunnels in or around the dam that created the reservoir. Hydro is considered to be renewable because the hydrologic cycle will continue to create at least some rain indefinitely. The kinetic pressure of the flowing water turns the turbine directly, allowing electricity to be generated without any combustion, thus qualifying hydro as a renewable.[92]

The reliability of hydro is qualified by two factors: (1) the amount of water in the reservoir or river flow, which depends on the amount of precipitation in the watershed, a quantity that varies seasonally and from year to year; (2) the extent to which the water in the reservoir is in demand for other uses for which few alternative water sources are available.[93]

Much of the hydro in the United States is located in the high

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[90] Glenn R. Schleede has been one of the main critics of wind power subsidies. *See, e.g.*, Letter from Glenn Schleede to Tim MacDonald, Senior Vice President, Meridian Clean Fuels, LLC (July 12, 2003), *available at* http://www.mnforsustain.org/windpower_money_changing_wealth_transfers_schleede_g.htm.

[91] Energy Policy Act of 2005, Pub. L. No. 109-58, §§ 202, 1301, 119 Stat. 594, 651–52, 986–90 (2005). Earlier wind subsidy programs are discussed in Avi Brisman, *The Aesthetics of Wind Energy Systems*, 13 N.Y.U. ENVTL. L.J. 1, 55–61 (2005).

[92] *See* U.S. Dep't of Energy, Energy Efficiency and Renewable Energy, How Hydropower Works, http://www1.eere.energy.gov/windandhydro/hydro_how.html (last visited Feb. 9, 2007). Hydro is treated as a renewable source by the Energy Information Agency. *See, e.g.*, ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, RENEWABLE ENERGY ANNUAL 2004, at 22 tbl.11, 23 tbl.12 (2006), *available at* http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea.pdf [hereinafter RENEWABLE ENERGY ANNUAL].

[93] *See* MASTERS, *supra* note 26, at 144 (stating "hydroelectric plants . . . must be operated with multiple constraints including the need for proper flows for downstream ecosystems, water supply, and irrigation"); SMIL, *supra* note 16, at 246, 257; WORLD COMM'N ON DAMS, DAMS AND DEVELOPMENT: A NEW FRAMEWORK FOR DECISION-MAKING, at xxxi, 78–80 (2000) (noting that, "[l]arge dams display a high degree of variability in delivering predicted water and electricity services"); Uranium Info. Ctr. Ltd., Nuclear Issues Briefing Paper 38, Renewable Energy and Electricity (2007), http://www.uic.com.au/nip38.htm (noting that "utilisation of stored water is sometimes complicated by demands for irrigation which may occur out of phase with peak electrical demands").

mountain regions of the western states.[94] Climatologists are forecasting that future precipitation during the winter wet season is likely to include more rain and less snow in these mountains, and the snow that falls will melt earlier in the year.[95] If this proves to be true, the water that is now made available by the annual snowmelt will not be available during the hot weather when both electric companies and agricultural users need it the most.[96] Disputes between these two interests are already common, and likely to get worse, reducing the reliability of hydro as a source for electric generation.[97]

Supplementing existing hydro sources with new ones would require the construction of many large dams.[98] From an engineering standpoint, the number of locations in the United States in which such dams could be built are quite limited.[99] Building on these sites would often create serious issues related to relocation, aquatic wildlife, disruption of existing recreation patterns, and destruction of protected parks and other sites of major ecological value.[100] Consequently, few energy analysts project substantial increases in hydro supplies.[101]

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[94] *See generally* ELECTRIC POWER MONTHLY NOVEMBER, *supra* note 52, at 37 tbl.1.13.A (showing a breakdown of hydroelectric power by state).

[95] Barnett et al., *supra* note 80, at 303, 305.

[96] *See id.*; *see also* ELECTRIC POWER MONTHLY NOVEMBER, *supra* note 52, at 17 tbl.1.1 (showing increased hydropower generation in May, June, and July); State of Cal., Agricultural Water Use Program, http://www.owue.water.ca.gov/agdev/ (last visited Jan. 12, 2007) (explaining that agriculture relies on snowmelt water and that agricultural demand for water is highest in the summer).

[97] *See* NORRIS HUNDLEY, JR., THE GREAT THIRST: CALIFORNIANS AND WATER, 1770S–1990S, at 353–85 (1992); *see also* Holly Doremus & A. Dan Tarlock, *Fish, Farms and the Clash of Cultures in the Klamath Basin*, 30 ECOLOGY L.Q. 279 (2003) (discussing the ongoing conflict over water in the Klamath River in Oregon and California).

[98] There has been discussion of distributed generation, which involves the use of small scale generation technologies close to the consumer. However, hydropower plants of this type are unlikely to make a significant contribution to the generation mix. *See* MORGAN ET AL., *supra* note 19, at 42–45.

[99] *See* WORLD COMM'N ON DAMS, *supra* note 93, at 9.

[100] *See* BOSSELMAN ET AL., *supra* note 11, at 173–74 (describing opposition to hydropower development); *see also* Udall v. Fed. Power Comm'n, 387 U.S. 428, 435–44 (1966) (outlining some effects of hydroelectric power dams).

[101] "In the view of many people, countries such as the USA . . . have already reached the practicable potential for large-scale hydro." Janet Ramage, *Hydroelectricity*, *in* RENEWABLE ENERGY: POWER FOR A SUSTAINABLE FUTURE 147, 190 (Godfrey Boyle ed., 2004); *see also* ANNUAL ENERGY OUTLOOK 2006, *supra* note 42, at 81.

Hydro, wind, and solar energy all require high initial capital investment but have very low operating costs.[102] Anyone making the investments needed to build these facilities has a strong incentive to use the power they generate whenever it is available. But because storage of electricity is possible only at very small scales and at high costs, when there is a demand for electricity, the electric utility must be able to supply it instantaneously, and if the wind isn't blowing or the sun isn't shining or it hasn't rained much, other reliable sources must be there to replace the unreliable sources.[103] This means that any estimate of the true cost of wind, solar, and hydro should factor in a share of the capital cost of the needed backup facilities.[104]

2. *All Currently Used Renewables Are Geographically Constrained*

Another handicap that most sources of renewable energy face as potential supplies of base-load electrical power is that they are immobile—they must be created where the wind blows, the sun shines, or the dam can be built.[105] Most other energy sources, such as coal, uranium, oil, or natural gas, can be delivered to a site of a generating plant that will be conveniently located in relation to sources of electricity demand and to the transmission network.

Electricity is and always can be transmitted long distances over high-voltage transmission lines, but because people who live near the site of a proposed transmission line typically oppose its construction, state and local officials have "strong incentives to protect their own incumbent firms or citizens, rather than supporting interstate cooperative market norms."[106] Consequently,

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[102] *See* MASTERS, *supra* note 26, at 144.

[103] *See* WARKENTIN-GLENN, *supra* note 3, at 9.

[104] *See supra* Part I.A.

[105] *See, e.g.*, NAT'L COMM'N ON ENERGY POLICY, SITING CRITICAL ENERGY INFRASTRUCTURE: AN OVERVIEW OF NEEDS & CHALLENGES 22 (2006) (noting that wind resources are often located far from centers of electricity demand and that dams face siting challenges); Bob Everett, *Solar Thermal Energy*, *in* RENEWABLE ENERGY: POWER FOR A SUSTAINABLE FUTURE, *supra* note 101, at 18, 22–24 (noting that solar radiation is highest near the equator and especially in sunny desert areas).

[106] Jim Rossi, *Transmission Siting in Deregulated Wholesale Power Markets: Re-Imagining the Role of Courts in Resolving Federal-State Siting Impasses*, 15 DUKE ENVTL. L. & POL'Y F. 315, 318–19 (2005).

such lines are costly and very difficult to build.[107] A percentage of the energy is lost with each mile of distance.[108] To get a true cost for power from remote sources, the cost and difficulty of providing transmission must be factored into the equation. In some parts of the world, such as Denmark and Northern Germany, the reliability of offshore winds in the Baltic Sea near major population centers has encouraged large-scale offshore windfarm construction,[109] but its true cost-effectiveness is hard to determine because the extent of subsidies involved is complex.[110] Whether similar conditions exist in many parts of the United States, and whether the opposition to such farms can be overcome, remains to be seen.[111]

Proposals to build windfarms in the United States "have often met resistance from individuals claiming that the turbines are stark intrusions in the natural landscape."[112] Another location problem with windfarms is that many of the places where winds are most reliable are also, for that very reason, sites used by migratory birds and bats that use wind currents to speed their migration in enormous numbers.[113] It is known that wind farms can kill flying animals, but the extent of the problem is not yet fully known.[114]

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[107] *See* Joseph T. Kelliher, Symposium Remarks, *The Need for Mandatory Electric Reliability Standards and Greater Transmission Investment*, 39 U. RICH. L. REV. 717, 728–29 (2005). Many of the proposed new coal plants in the western states are located near the coal mines and would require long transmission lines to carry the power to market. *See* U.S. DEP'T OF ENERGY, *supra* note 7, at 49–57.

[108] *See* U.S. DEP'T OF ENERGY, *supra* note 7, at 13.

[109] *See, e.g.*, SWEET, *supra* note 9, at 152–55.

[110] *See id.*

[111] Many utility analysts doubt that wind power will make drastic changes in the overall fuel mix in the United States. *See* Hunt & Given, *supra* note 37, at 10; *see also* Brisman, *supra* note 91 (arguing that increased aesthetic appreciation of wind energy systems may help overcome opposition to them).

[112] Brisman, *supra* note 91, at 6–8 (internal quotation marks omitted).

[113] *See* HAWK MOUNTAIN SANCTUARY, WIND POWER AND RAPTORS: THEIR INTERACTIONS AND WAYS TO REDUCE THEM (2006), http://www.hawkmountain.org/raptor_conservation/Hawk%20Mountain%20Principles%20of%20Raptor%20Conservation.Wind%20Power.pdf; *see also* HAWK MOUNTAIN, BIRDLIFE CONSERVATION SERIES NO. 9, RAPTOR WATCH: A GLOBAL DIRECTORY OF RAPTOR MIGRATION SITES 74 (Jorje I. Zalles & Keith L. Bildstein eds., 2000) (bald eagle migration patterns have been altered by electric-generation turbines).

[114] *See generally* AM. WIND ENERGY ASS'N & AM. BIRD CONSERVANCY, PROCEEDINGS OF THE WIND ENERGY AND BIRDS/BATS WORKSHOP (2004), *available at* http://www.awea.org/pubs/documents/WEBBProceedings9.14.04%5BFinal%5D.pdf. As Lovejoy and Hannah have

These concerns may constrain the ability to place a windfarm where one might otherwise be warranted by demand and high winds.

3. *Development of New Renewable Sources Is Not Imminent*

Few people would disagree with the idea that renewable energy research and development is desirable, and support for such work continues to come from both the public and private sectors. Virtually every day brings news of a new proposal somewhere in the world to develop another system of producing electricity renewably,[115] but few energy analysts believe that new systems of large-scale renewable generation are likely in the next few decades.[116]

One other existing renewable source of electricity is the burning of vegetative material.[117] In the United States, the burning of wood chips in cogeneration plants has been producing

pointed out: "Many renewable energy technologies that are environmentally benign at small scales have major environmental consequences when applied at the scale necessary to reduce current fossil fuel consumption." Thomas E. Lovejoy & Lee Hannah, *Global Greenhouse Gas Levels and the Future of Biodiversity*, *in* CLIMATE CHANGE AND BIODIVERSITY 387, 391 (Thomas E. Lovejoy & Lee Hannah eds., 2005). *Compare* Ctr. for Biological Diversity, Fact Sheet on Altamont Pass Bird Kills, http://www.biologicaldiversity.org/swcbd/Programs/bdes/altamont/factsheet.pdf (last visited Feb. 9, 2007), *with* Power Works, Pacific Winds, Renewable Wind Power and Solar Power, http://www.powerworksinc.com/environment.asp (last visited Feb. 9, 2007).

[115] *See* Virginia Gewin, *Burst of Energy: More and More Venture Capitalists are Backing Clean Technology in the United States, but Will It Take Off?*, 441 NATURE 810 (2006).

[116] *See, e.g.*, SWEET, *supra* note 9, at 159 (stating that "[i]t is wishful thinking to imagine that renewables can displace more than a fraction of centrally generated electricity").

[117] Burning vegetation is often considered to be a form of renewable energy. Even though it speeds up the release of greenhouse gases, it does not increase the total emissions in the long run. Vegetation grows and eventually dies. Over time, the plant material rots and the carbon in it is released to the air. If the vegetation is burned, it hastens the release of carbon dioxide to the atmosphere, but does not increase the overall total release of carbon dioxide. If new vegetation replaces the old, the combustion of biomass, as it has come to be known, is generally considered to be a use of a renewable resource. From a short-run standpoint, the air pollution it creates is very significant. The burning of wood is a common phenomenon in many parts of the world. Indeed, burning of biomass in Southeast Asia has contributed to the "Asian brown cloud" that pollutes the atmosphere seasonally. *See* RENEWABLE ENERGY ANNUAL, *supra* note 92 (including energy from burning vegetation as renewable); SWEET, *supra* note 9, at 50–60 (noting the "Asian brown cloud" that pollutes the atmosphere seasonally is largely caused by vegetation fires).

electricity for the lumber and paper industries,[118] and there have been scattered successful examples of the use of municipal solid waste to produce electricity,[119] but most of the current interest in biomass relates to converting it to transportation fuel in the form of ethanol or biodiesel fuel.[120] There is little likelihood that biomass combustion will be a significant source of electric energy for the future.

If the production and storage of hydrogen ever proves to be the first efficient way of storing large amounts of electrical energy, as many people hope, this will provide another effective way of reducing the need for peaking facilities. Electricity from such sources as wind and solar energy could be stored and used to meet base-load needs. However, more basic research and development is needed before a "hydrogen economy" will be realized.[121]

In summary, renewable sources of electricity are likely to play an important role in supplying electricity for intermediate and peaking needs in the United States, but their unreliability, their often inconvenient location, and the potential problems of new technology development, make it unlikely that they will compete with coal and nuclear as sources of base-load power except under unusual circumstances.

II. FROM AN ECOLOGICAL STANDPOINT, NUCLEAR POWER IS MUCH BETTER THAN COAL

Examining coal and nuclear power solely from an ecological standpoint, the advantages of nuclear power are clear.

[118] *See* RENEWABLE ENERGY ANNUAL, *supra* note 92, at 17 tbl.8.

[119] *See id.* at 1, 16 tbl.7.

[120] *See* NAT'L COMM'N ON ENERGY POLICY, *supra* note 105, at 19, 70–78.

[121] *See generally* Peter M. Crofton, *Emerging Issues Relating to the Burgeoning Hydrogen Economy*, 27 ENERGY L.J. 39 (2006) (discussing issues related to widespread hydrogen use). The opportunities for use of hydrogen for electricity generation appear to be far more feasible than the large-scale use of hydrogen in vehicles. *See* JOSEPH J. ROMM, THE HYPE ABOUT HYDROGEN 12–21 (2004). But if the "hydrogen economy" becomes a reality, it is likely to be decades from now. *See* NAT'L RESEARCH COUNCIL, THE HYDROGEN ECONOMY: OPPORTUNITIES, COSTS, BARRIERS, AND R&D NEEDS 116–20 (2004). And it is quite possible that the hydrogen will be generated by nuclear power. *See generally* CHARLES FORSBERG, FUTURES FOR HYDROGEN PRODUCED USING NUCLEAR ENERGY (2004).

A. *The Ecological Impacts of Every Stage of the Use of Coal Are Disastrous*

Virtually all of the coal mined in the United States is used as boiler fuel to generate electricity,[122] and although few users of that electricity realize it, half of the nation's electric energy is provided by coal.[123] In his recent book, *Big Coal*, Jeff Goodell points out that in the United States, the mining and combustion of coal typically occur in such remote locations that most Americans have no idea "what our relationship with this black rock actually costs us."[124] This is particularly true with regard to public understanding of ecological systems that are being destroyed in remote places or through chains of causation that only experts understand. Coal is ecologically destructive through (1) mining, (2) air pollution, (3) greenhouse gas emissions, and (4) water pollution; and (5) while so-called "clean-coal" technology is a long-range hope, it is not likely to be common in the next decade.

1. *Coal Mining Is Destroying Vast Amounts of Natural Landscape*

Originally, almost all coal mining took place through the construction of a network of shafts underground from which coal would be cut and brought to the surface. Such "underground" mining still takes place in the United States,[125] but each year a

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[122] Over 92% of United States coal is being burned in power plants. *See* ANNUAL ENERGY REVIEW 2005, *supra* note 27, at 209 tbl.7.3.

[123] *See* ELECTRIC POWER ANNUAL 2005, *supra* note 43, at 1 fig.ES1.

[124] JEFF GOODELL, BIG COAL: THE DIRTY SECRET BEHIND AMERICA'S ENERGY FUTURE, at xii (2006).

> From the consumer's perspective, coal has virtually disappeared—its sooty black chunks magically transformed into squeaky-clean electrons. Now that nine out of every ten tons of the nation's coal vanishes into power plants, many Americans can harbor the illusion that coal is no longer a major energy source or big environmental threat, even while the nation burns more of it than ever.

BARBARA FREESE, COAL: A HUMAN HISTORY 166 (2003).

[125] *See* GOODELL, *supra* note 124, at 19. It is beyond the scope of this article to discuss the impacts of coal mining on human health, but recent coal mining accidents, in the United States, China, and elsewhere, have attracted world-wide attention, and the less dramatic but far more numerous cases of black lung and other diseases of coal miners have justified its reputation as one of the world's most hazardous occupations. *See* ROBERT C. MORRIS, THE ENVIRONMENTAL CASE FOR NUCLEAR POWER: ECONOMIC, MEDICAL, AND POLITICAL CONSIDERATIONS 132–33 (2000); *see also, e.g.*, *China Mine Accident Kills More*

larger share of the mining is "surface" mining.[126] Both kinds of coal mining have an impact on the landscape both directly and indirectly.

Underground mining typically brings to the surface large volumes of minerals, only some of which constitutes usable coal.[127] The residue is known as "gob" or "culm" and residue piles from both existing and abandoned underground mines are common sights in older mining areas.[128] The rain penetrates the piles and leaches out the soluble material, creating sulfuric and other acids, which are supposed to be stored in impoundments on the mine site but often flow directly into local watersheds or potable aquifers, particularly if the mine has been abandoned.[129] This kind of acid mine drainage pollutes streams throughout older mining regions, often turning them bright orange, rendering the water non-potable and uninhabitable by wildlife, and changing the ecological processes on the riparian landscape far beyond the mine site.[130]

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than 200, N.Y. TIMES, Feb. 15, 2005, at A8; Gardiner Harris, *Endemic Problems of Safety in Coal Mining*, N.Y. TIMES, Jan. 10, 2006, at A13; James C. McKinley Jr., *With 65 Still Entombed at Mexican Mine, Ache Deepens*, N.Y. TIMES, Mar. 3, 2006, at A3.

[126] *See* ANNUAL ENERGY REVIEW 2005, *supra* note 27, at 207 tbl.7.2. In 2004, nineteen surface mines in Wyoming produced 396,000 tons of coal. In the entire Appalachian region, there are 530 underground mines and 663 surface mines that produced a total of only 390,000 tons in that year. ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ANNUAL COAL REPORT 2005, at 12 tbl.1 (2006), *available at* http://www.eia.doe.gov/cneaf/coal/page/acr/acr.pdf [hereinafter ANNUAL COAL REPORT 2005].

[127] *See, e.g.*, M. Karmis & Z. Agioutantis, *A Risk Analysis Subsidence Approach for the Design of Coal Refuse Impoundments Overlying Mine Workings*, *in* PROC. EIGHTH INT'L SYMP. ON ENVTL. ISSUES AND WASTE MGMT. IN ENERGY AND MINERAL PRODUCTION (SWEMP) 205, 205 (2004), *available at* http://www.energy.vt.edu/Publications/2004_SWEMP_Risk.pdf.

[128] *See* COMM. ON MINE PLACEMENT, NAT'L RESEARCH COUNCIL, MANAGING COAL COMBUSTION RESIDUES IN MINES 16, 49 (2006).

[129] *See* GOODELL, *supra* note 124, at 25–26. For the United States Geological Survey's material on acid mine drainage, see U.S. Geological Survey, Mine Drainage, http://geology.er.usgs.gov/eastern/environment/drainage.html (last visited Feb. 9, 2007).

[130] *See* U.S. Geological Survey, *supra* note 129; Greenpeace, Acid Mine Drainage: Devastating to Aquatic Life, http://www.greenpeace.org/raw/content/usa/press/reports/acid-mine-drainage-devastatin.pdf (last visited Feb. 9, 2007). Acid mine drainage contains sulfuric acid and iron, and may dissolve metals such as manganese, zinc, and nickel. The drainage is toxic to aquatic animals, and some metals bioaccumulate in the food chain. *See* CLEAN AIR TASK FORCE, CRADLE TO GRAVE: THE ENVIRONMENTAL IMPACTS OF COAL 2 (2001), *available at* http://www.catf.us/publications/reports/Cradle_to_Grave.pdf; OFFICE OF SOLID WASTE, U.S. EPA, ACID MINE DRAINAGE PREDICTION 1–5, 42 (1994),

Underground mining also destroys landscapes through subsidence. If a mine shaft is not properly supported, its roof will collapse, which typically causes the surface of the earth over the mine to subside. In older mines, such subsidence regularly happened only after a mineshaft was abandoned, but many newer mines use a system called "longwall" mining, which makes no attempt to support the roof over the area where coal is removed, resulting in intentional subsidence. Both intentional and unintentional subsidence can change drainage patterns on the surface in ways that may destroy existing ecosystems.[131]

Even more directly damaging to the natural landscape is surface mining, which now produces the majority of our coal.[132] The two most prominent examples of surface mining in the United States and the resulting ecological consequences are in the Powder River Valley of Wyoming, and in a section of the Southern Appalachians that includes parts of Virginia, West Virginia, Kentucky, and Tennessee.[133] In both areas, surface mining is used extensively, but the differences in the terrain result in quite different impacts.[134]

The Powder River Valley is relatively flat and dry rangeland, supporting cattle and, in the streams, trout.[135] The coal seams in this valley tend to be massive, and the parts that have been mined are relatively close to the surface.[136] The earth overlying the coal,

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available at http://www.epa.gov/epaoswer/other/mining/techdocs/amd.pdf; Pa. Envtl. Prot. Agency, The Science of Acid Mine Drainage and Passive Treatment, http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_AMD.htm (last visited Feb. 9, 2007).

[131] BOSSELMAN ET AL., *supra* note 11, at 223–26.

[132] In 2004, 2/3 of our coal came from surface mines and only 1/3 from underground mines. ANNUAL COAL REPORT 2005, *supra* note 126, at 17 tbl.2.

[133] *See id.* at 13 tbl.1; GOODELL, *supra* note 124, at 4–6, 21–42.

[134] *See* ANNUAL COAL REPORT 2005, *supra* note 126, at 13 tbl.1.

[135] *See* Nat'l Agricultural Statistics Serv., U.S. Dep't of Agriculture, 2002 Census of Agriculture County Profile: Powder River, Montana, http://www.nass.usda.gov/census/census02/profiles/mt/cp30075.PDF (last visited Jan. 5, 2007); Montana's Official State Web Site, Powder River, http://fwp.mt.gov/fishing/guide/q_Powder_River__1054362467419.aspx (last visited Jan. 5, 2007); U.S. Forest Service, Ecological Subregions of the United States, http://www.fs.fed.us/land/pubs/ecoregions/ch41.html (last visited Jan. 5, 2007).

[136] *See* EQUAL. STATE POLICY CTR., COAL COMPANIES WELL-POSITIONED FOR CONTINUED GROWTH IN THE POWDER RIVER BASIN (2000), http://www.equalitystate.org/ESPC%20Website%20Generic%20Pages/workprogramfolder/Coal%20Report/coal_growth.html.

known in the trade as "overburden," is blasted with explosives and then removed by massive machines built for the purpose.[137] The scale of the operations is so large that seventeen Wyoming surface mines supply over a third of U.S. coal consumption.[138] Despite the effects from the dust created in these operations, the Environmental Protection Agency (EPA) recently proposed to classify such dust as a non-pollutant.[139] In December 2005, the EPA issued proposed rules that would exempt mining operations in rural areas from dust emission regulations.[140]

In the Southern Appalachians, surface mining is taking place in a forested landscape of rolling hills and mountains with relatively moist conditions.[141] The current mining method is known as "mountaintop mining," and involves blasting and scraping off the tops of mountains to obtain access to the coal underneath. In an earlier era, this coal would have been accessed by underground shafts, but today's massive machinery and cheap explosives makes it more economical to remove the mountaintop and use surface mining equipment to take out the coal.[142]

The rubble that was once the top of the mountain is simply dumped into a valley adjacent to the mountain, creating what is euphemistically called "valley fill." The result is the destruction

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[137] *See* GOODELL, *supra note* 124, at 16–18; Energy Info. Admin., Coal Industry Terms, http://www.eia.doe.gov/cneaf/coal/page/gloss.html (last visited Feb. 20, 2007) (definition of "overburden").

[138] *See* ANNUAL COAL REPORT 2005, *supra* note 126, at 17 tbl.2, 53 tbl.26 (showing that surface mines in Wyoming produced 403,908,000 short tons of coal in 2005, which is 35% of the 1,125,476,000 short tons consumed in the United States in 2005).

[139] J.R. Pegg, *Science and Politics Collide as EPA Considers New Air Rule*, ENV'T NEWS SERV., July 25, 2006, http://www.ens-newswire.com/ens/jul2006/2006-07-25-10.asp. In the final rule, the EPA backed away from the blanket exemption of mining from the regulation, but said it believed there was a distinct difference between urban and rural dust and would undertake further research. National Ambient Air Quality Standards for Particulate Matter, 71 Fed. Reg. 61,144, 61,150, 61,187–89 (Oct. 17, 2006) (to be codified at 40 C.F.R. pt. 50).

[140] Final rules must be issued by September 2007 to meet a court-imposed deadline. The proposed rules have been very controversial. *See* Janet Wilson, *EPA Panel Advises Agency Chief to Think Again*, L.A. TIMES, Feb. 4, 2006, at B1.

[141] *See* Overview of the Southern Appalachian Mountains, http://www.unc.edu/~dcrawfor/overap.htm (last visited Jan. 5, 2007).

[142] For a first-hand account of mountaintop mining, see ERIK REECE, LOST MOUNTAIN (2006); *see also* GOODELL, *supra* note 124, at 21–47. For photographs of mountaintop mining, see John G. Mitchell, *When Mountains Move*, NAT'L GEOGRAPHIC, Mar. 2006, at 104.

not only of the ecological characteristics of the mountain itself but also of the adjacent valley.[143] Although this destruction has been widely criticized, it continues to be supported by both federal and state regulating agencies.[144]

Although reserves of coal in the United States remain plentiful, the quality and accessibility of the coal is likely to decline.[145] "A good percentage of the coal that's left is too dirty to be burned in conventional power plants, and much of it is buried in inconvenient places—under homes, schools, parks, highways, and historical landmarks."[146] A future shortage of good quality coal may add to the ecological destruction involved in coal mining by requiring more disruption to get at equivalent amounts of coal.[147]

2. *Coal Combustion Pollutes a Wide Range of Environments*

In their recent "Nutshell" book on energy law, Joseph Tomain and Richard Cudahy concisely summarize the primary types of air pollution caused by coal combustion:

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[143] Kentuckians for the Commonwealth, Inc. v. Rivenburgh, 204 F. Supp. 2d 927, 930 (S.D.W. Va. 2002).

[144] In 2002, the U.S. Army Corps of Engineers issued Nationwide Permit 21, which authorizes discharges of dredged or fill material that (1) are associated with surface coal mining and reclamation operations, so long as those operations are authorized by the Department of Interior or by states with approved programs under the Surface Mining Control and Reclamation Act of 1977, (2) are preceded by notice to the Corps, and (3) are approved by the Corps after the Corps concludes that the activity complies with the terms of the nationwide permit and that its adverse environmental effects are minimal both individually and cumulatively. Issuance of Nationwide Permits, 67 Fed. Reg. 2019, 2081 (Jan. 15, 2002). The regulation was upheld in *Ohio Valley Environmental Coalition v. Bulen*, 429 F.3d 493, 505 (4th Cir. 2005). For another Fourth Circuit decision upholding regulations favoring mountaintop mining, see *Kentuckians for the Commonwealth, Inc. v. Rivenburgh*, 317 F.3d 425, 447–48 (4th Cir. 2003). *See generally* GOODELL, *supra* note 124.

[145] WILLIAM F. RUDDIMAN, PLOWS, PLAGUES, AND PETROLEUM: HOW HUMANS TOOK CONTROL OF CLIMATE 162 (2005).

> The types of coal that provide the most energy per ton were mined earliest, and much of the coal that remains is less efficient and rich in sulfur, which accumulated in those ancient swamps along with the plant carbon. As coal begins to replace oil and gas as an energy source, both CO_2 and sulfur emissions will go up for each unit of energy used.

Id.

[146] GOODELL, *supra* note 124, at 7. The amount of recoverable coal reserves in the United States is the subject of widely varying predictions. *See id.* at 12–15.

[147] *See generally* ANNUAL ENERGY REVIEW 2005, *supra* note 27, at 296 tbl.7.8 (showing that coal prices increased sharply from 2003 to 2005).

> Coal combustion generates four main sources of pollution: sulfur oxide, nitrogen oxide, carbon dioxide, and particulate matter; all of which spoil land, water, and air. Sulfur oxide, which increases with the sulfur content of the coal, causes human health problems, crop damage, and acid rain. Nitrogen oxide contributes to the same problems and causes smog. Tons of particulate matter are emitted from coal burning facilities daily and cause property damage and health hazards. Finally, carbon dioxide causes what is known as the greenhouse effect, which is an increase in the temperature of the earth's surface.[148]

We have long known that air pollution from coal combustion damages crops and natural vegetation, in addition to its impact on human health.[149] In the last thirty years, scientists have learned that pollutants from coal-burning power plants travel long distances[150] and create acid rain that significantly harms plants and animals.[151]

Acid rain is formed when sulfates and nitrates emitted by the tall stacks of coal-burning power plants react with rainwater to form acids that are deposited on the landscape many miles away from where the pollutants were emitted.[152] In 1990, when Congress finally enacted acid rain legislation, the assumption was that sulfuric acid was the main harmful component of acid rain,[153] and the statute imposed limits of sulfur emissions but less strict limits on nitrogen emissions.[154]

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[148] TOMAIN & CUDAHY, *supra* note 3, at 240–41.

[149] *See* FREESE, *supra* note 124, at 37.

[150] *See, e.g.*, Keith Bradsher & David Barboza, *Pollution From Chinese Coal Casts Shadow Around Globe*, N.Y. TIMES, June 11, 2006, at A1.

[151] *See generally* GARY C. BRYNER, BLUE SKIES, GREEN POLITICS: THE CLEAN AIR ACT OF 1990, at 68 (1993).

[152] *See* EPA, What is Acid Rain?, http://www.epa.gov/acidrain/index.html (last visited Feb. 9, 2007) [hereinafter What is Acid Rain?]. Coal-fired power plants are by far the largest anthropogenic source of sulfur dioxide emissions. Such plants contribute about 40% of the emissions of nitrogen oxides, but because power plants emit nitrogen oxides from tall stacks, these nitrogen oxides travel farther than those emitted by other leading sources, such as motor vehicles. *See* EPA, NITROGEN: MULTIPLE AND REGIONAL IMPACTS 5, 7 (2002), *available at* http://www.epa.gov/airmarkets/articles/nitrogen.pdf; INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2004, *supra* note 72, at 2–30; *see also* What is Acid Rain?, *supra*.

[153] BRYNER, *supra* note 151, at 68 ("The primary source of acid rain is sulfur oxides.").

[154] *See* Kate M. Joyce, *Who'll Stop the Rain?*, 7 ALB. L. ENVTL. OUTLOOK 94, 103–06 (1994). The Clean Air Act specifically forbids EPA from requiring power plants to use post-combustion nitrogen removal technology. 42 U.S.C.

Many scientists now believe that nitrogen oxides play a larger role in acid rain than was earlier realized,[155] and may be as important, or even more important, than sulfur emissions,[156] perhaps because nitrogen interacts with other elements more extensively.[157] Acid rain continues to kill trees and fish in many parts of the eastern states and Canada,[158] and the relative roles of nitrogen and sulfur in the production of acid rain continue to be explored by scientists.[159]

Now scientists are also demonstrating that mercury emitted from coal-burning power plants poisons ecosystems, and by doing

§ 7651f(d) (2000). Post-combustion removal technologies, which are widely used elsewhere in the world, include selective non-catalytic NO_x reduction (SNCR), selective catalytic reduction (SCR), and combined SO_2/NO_x removal. For a concise description of these methods, see C. DAVID COOPER & F. C. ALLEY, AIR POLLUTION CONTROL: A DESIGN APPROACH 505–09 (2d ed. 1986). *See also* E. STRATOS TAVOULAREAS & JEAN-PIERRE CHARPENTIER, CLEAN COAL TECHNOLOGIES FOR DEVELOPING COUNTRIES 16, 17 fig.2.1, 32–36 (World Bank Technical Paper No. 286, 1995), *available at* http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2004/10/21/000112742_20041021121653/Rendered/PDF/wtp2860entire0report.pdf.

[155] *See* Joyce, *supra* note 154, at 113–14.

[156] *See generally id.* Ironically, one of the contributors to acid rain may be the decline in emissions of particulate matter due to stricter air pollution controls. Particulate matter provides base cations that help neutralize acid deposition. *See* HUBBARD BROOK RESEARCH FOUND., ACID RAIN REVISITED 5 (2001), http://www.hubbardbrook.org/hbrf/publications/Acid_Rain_Revisited.pdf.

[157] Sulfur deposited from the air is either passively stored or lost by streamwater discharge, while nitrogen may "be stored, recycled, lost to the atmosphere or lost via drainage waters. As such it has a more extensive interaction with other elements over much larger scales of time and space." James N. Galloway, *Acid Deposition: S and N Cascades and Elemental Interactions*, *in* INTERACTIONS OF THE MAJOR BIOGEOCHEMICAL CYCLES: GLOBAL CHANGE AND HUMAN IMPACTS 259, 263 (Sci. Comm. on Problems of the Env't Series No. 61, Jerry M. Melillo et al. eds., 2003) *see also* J.W. ERISMAN ET AL., THE DUTCH NITROGEN CASCADE IN THE EUROPEAN PERSPECTIVE 67 tbl.3.11 (2005), *available at* http://www.ecn.nl/docs/library/report/2005/c05007.pdf (summarizing effects of nitrogen on the environment and ecosystem).

[158] "The Canadian government has found that even after full implementation of the U.S. Acid Rain Program, thousands of Canadian lakes in an area the size of France and the United Kingdom combined will continue to acidify." FREESE, *supra* note 124, at 171; *see also* The Green Lane, The Current Status of Acid Deposition Science in Canada, http://www.ec.gc.ca/acidrain/new.html (last visited Feb. 9, 2007).

[159] *See generally, e.g.*, ACID RAIN 2005: 7TH INTERNATIONAL CONFERENCE ON ACID DEPOSITION, CONFERENCE ABSTRACTS (Iva Hůnová et al. eds., 2005), *available at* http://www.acidrain2005.cz/sbornik.html.

so, endangers human health.[160] Coal burning is the largest uncontrolled non-natural source of mercury.[161] Although most attention has understandably been paid to mercury's impact on human health, the direct source of that impact is the bioaccumulation of mercury in organisms consumed by humans, especially fish.[162] Research increasingly shows that this bioaccumulation is affecting a wide range of animals in addition to the fish that are the most important source of mercury consumed by humans.[163] The EPA has been widely criticized for delaying effective regulation of mercury,[164] and many states are preparing to impose tighter restrictions.[165]

Other heavy metals, such as arsenic and lead, are found in greater or lesser degrees in various coal seams,[166] and research on

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[160] "Most mercury in lakes rains down from the air, and perhaps as much as a third of mercury emissions to the air comes from coal plants, making them the largest source." FREESE, *supra* note 124, at 173. For a concise summary, see CLEAN AIR TASK FORCE, *supra* note 130.

[161] ROBERT B. FINKELMAN & JOSEPH E. BUNNELL, HEALTH IMPACTS OF COAL 37 (2003), http://pubs.usgs.gov/of/2004/1283/shortcoursea.pdf.

[162] *See* COMM. ON THE TOXICOLOGICAL EFFECTS OF METHYLMERCURY, NAT'L RESEARCH COUNCIL, TOXICOLOGICAL EFFECTS OF METHYLMERCURY 16 (2000); Jocelyn Kaiser, *Mercury Report Backs Strict Rules*, 289 SCI. 371, 371 (2000).

[163] New research reveals the poison is more deadly to wildlife than previously thought, affecting forest songbirds and other species that do not eat fish. *See* Charles T. Driscoll et al., *Mercury Contamination in Forest and Freshwater Ecosystems in the Northeastern United States*, 57 BIOSCIENCE 17, 25 (2007) (finding higher levels of mercury in some species that do not eat fish compared to those that do eat fish); David C. Evers et al., *Biological Mercury Hotspots in the Northeastern United States and Southeastern Canada*, 57 BIOSCIENCE 29, 35, 41 (2007) (noting mechanisms whereby forests accumulate mercury found in the atmosphere and the need for novel indicator species that may not be directly linked to aquatic food webs).

[164] The Clean Air Mercury Rule deadline for power plant operators to install pollution control equipment specifically designed to reduce mercury emissions by 90% is not until 2018. Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units, 70 Fed. Reg. 28,606, 28,606, 28,614–15 (May 18, 2005) (to be codified at 40 C.F.R. pts. 60, 72, 75). Judicial review of the rule is pending before the D.C. Circuit in numerous cases that have been consolidated in *New Jersey v. Envtl. Prot. Agency*, No. 05-1097, 2005 WL 3750257 (D.C. Cir. Aug. 4., 2005). *See also* Steven D. Cook, *11 States File Lawsuit over Mercury as EPA Publishes Emissions Trading Rule*, 36 BNA ENV'T REP. 1021 (2005). For the coal industry's role in the process, see GOODELL, *supra* note 124, at 141–46.

[165] *See, e.g.*, Pamela D. Harvey & C. Mark Smith, *The Mercury's Falling: The Massachusetts Approach to Reducing Mercury in the Environment*, 30 AM. J.L. & MED. 245, 263–81 (2004).

[166] *See* K.S. Sajwan et al., *Production of Coal Combustion Products and*

the ecological effects of burning coal containing these substances seems to be at a relatively early stage.[167]

3. *Carbon Dioxide from Coal Burning Negatively Affects Biodiversity*

Many studies have shown that climate change brought about by the increase of greenhouse gases, such as carbon dioxide, has had adverse ecological impacts.[168] Studies of the impact of climate change on animal species are already beginning to show significant changes to the geographical movements of animals that appear to be the result of changes in climate.[169] For example, mussel diversity along the California coast has declined in the face of warming water temperatures;[170] amphibian diversity in Costa Rican cloud forests has declined in the face of warmer and drier conditions;[171] and a study of 34 butterfly species found that their European ranges had shifted to the north from 35 to 240 kilometers.[172]

Their Potential Uses, *in* COAL COMBUSTION BYPRODUCTS AND ENVIRONMENTAL ISSUES 3, 3 (Kenneth S. Sajwan et al. eds., 2006); *see also* GOODELL, *supra* note 124, at 145–46.

[167] *See, e.g.*, Chunying Chen et al., *The Roles of Serum Selenium and Selenoproteins on Mercury Toxicity in Environmental and Occupational Exposure*, 114 ENVTL. HEALTH PERSP. 297 (2006); Mercedes Diaz-Somoano & M. Rosa Martinez-Tarazona, *Retention of Arsenic and Selenium Compounds Using Limestone in a Coal Gasification Flue Gas*, 38 ENVTL. SCI. & TECH. 899 (2004); *see generally* COAL COMBUSTION BYPRODUCTS AND ENVIRONMENTAL ISSUES, *supra* note 166 (compiling research on byproducts of coal combustion).

[168] Many such studies are reviewed and analyzed in CLIMATE CHANGE AND BIODIVERSITY, *supra* note 114, at 41–90. Impacts include "heritable, genetic changes in populations of animals as diverse as birds, squirrels, and mosquitoes." William E. Bradshaw & Christina M. Holzapfel, *Evolutionary Response to Rapid Climate Change*, 312 SCI. 1477, 1477 (2006); *see also* Camille Parmesan, *Ecological and Evolutionary Responses to Recent Climate Change*, 37 ANN. REV. OF ECOLOGY, EVOLUTION, & SYSTEMATICS 637 (2006).

[169] *See, e.g.*, Niclas Jonzén et al., *Rapid Advance of Spring Arrival Dates in Long-Distance Migratory Birds*, 312 SCI. 1959 (2006); Jeremy T. Kerr, *Butterfly Species Richness Patterns in Canada: Energy, Heterogeneity, and the Potential Consequences of Climate Change*, CONSERVATION ECOLOGY, Apr. 5, 2001, http://www.consecol.org/vol5/iss1/art10. For a recent review of many such studies, see BIRDS AND CLIMATE CHANGE (Anders P. Møller et al. eds., 2006).

[170] Jayson R. Smith et al., *Dramatic Declines in Mussel Bed Community Diversity: Response to Climate Change?*, 87 ECOLOGY 1153, 1159 (2006).

[171] J. Alan Pounds et al., *Biological Response to Climate Change on a Tropical Mountain*, 398 NATURE 611, 613 (1999).

[172] Bernice Wuethrich, *How Climate Change Alters Rhythms of the Wild*, 287 SCI. 793, 795 (2000). For a review of the various studies, see Camille Parmesan,

Plant species will also be significantly affected by climate change. Increased levels of carbon dioxide accelerate plant growth in laboratory studies,[173] but many botanists believe that any stimulative effects will be offset by declines in soil nutrient availability.[174] Moreover, the plants that could readily adapt to the new climate conditions may be far away and lack good dispersal capability.[175] And although some scientists hope that higher carbon dioxide levels will increase the ability of forests to store carbon, recent studies cast doubt on the extent to which this will occur.[176]

One analysis suggests that 15–37% of a sample of 1103 land plants and animals would eventually become extinct as a result of climate changes expected by 2050.[177] Not all of the projected climate change can be attributed to the combustion of coal, but coal's share of the responsibility for greenhouse gas emissions is very significant.[178]

Biotic Response: Range and Abundance Changes, *in* CLIMATE CHANGE AND BIODIVERSITY, *supra* note 114, at 41, 41–55.

[173] *See* CHARLES J. KREBS, ECOLOGY: THE EXPERIMENTAL ANALYSIS OF DISTRIBUTION AND ABUNDANCE 593–96 (5th ed. 2001); Stephen P. Long et al., *Food for Thought: Lower-Than-Expected Crop Yield Stimulation with Rising CO_2 Concentrations*, 312 SCI. 1918 (2006).

[174] Increased CO_2 resulting from climate change will cause little increased growth stimulation except where soil nitrogen is abundant, but even then the increase "will be constrained by declines in the nutrient availability due to the increased C/N ratio of plant litter, resulting in greater nitrogen immobilization by soil microbes." S.E. Hobbie et al., *Resource Supply and Disturbance as Controls over Present and Future Plant Diversity*, *in* BIODIVERSITY AND ECOSYSTEM FUNCTION 385, 385 (Ernst-Detlef Schulze & Harold A. Mooney eds., 1993).

[175] *See* Chris D. Thomas, *Recent Evolutionary Effects of Climate Change*, *in* CLIMATE CHANGE AND BIODIVERSITY, *supra* note 114, at 75, 75–88; David S. Woodruff, *Declines of Biomes and Biotas and the Future of Evolution*, 98 PROC. NAT'L ACAD. SCI. 5471, 5472 (2001).

[176] *See* William H. Schlesinger & John Lichter, *Limited Carbon Storage in Soil and Litter of Experimental Forest Plots Under Increased Atmospheric CO_2*, 411 NATURE 466, 467 (2001); Ram Oren et al., *Soil Fertility Limits Carbon Sequestration by Forest Ecosystems in a CO_2-Enriched Atmosphere*, 411 NATURE 469, 470 (2001).

[177] Chris D. Thomas et al., *Extinction Risk from Climate Change*, 427 NATURE 145, 145 (2004).

[178] *See* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, U.S. CARBON DIOXIDE EMISSIONS FROM ENERGY SOURCES: 2005 FLASH ESTIMATE (2006); NAT'L WILDLIFE FED'N, FUELING THE FIRE: GLOBAL WARMING, FOSSIL FUELS AND THE FISH AND WILDLIFE OF THE AMERICAN WEST, at i (2006), *available at* http://www.nwf.org/globalwarming/pdfs/FuelingTheFire.pdf.

4. *Solid Wastes from Coal Combustion Pollute Our Waters*

After coal is burned in a power plant, the solid noncombustible material is a waste product, often known as ash, which contains a highly complex and variable mix of the impurities found in coal, including mercury, selenium, thorium, radium, uranium and vanadium.[179] Each year coal-fired power plants produce about 130 million tons of this solid waste.[180]

Some ash is used in construction materials, but much of the ash is stored in impoundments at or near the power plant site.[181] If these impoundments are not properly maintained, rain can leach toxic materials from the ash into underground water supplies, and floods have sometimes washed out impoundment dams, sending tons of ash into communities and rivers, destroying their ecological viability.[182]

Uranium, radium, and thorium found in coal are naturally radioactive elements, and it is estimated that 500 tons of uranium are left in the ash produced by coal-fired power plants each year, some of which will decay, releasing radon gas.[183] The amounts of radioactivity involved are probably harmless, but the amount of radioactivity released by a coal-fired power plant exceeds that of a nuclear power plant, a fact that few people realize.[184] Radioactive emissions from coal-burning power plants cause some 320 deaths per year worldwide.[185]

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179 *See* MORRIS, *supra* note 125, at 44–46.

180 GOODELL, *supra* note 124, at 123.

181 *See* COMM. ON MINE PLACEMENT, *supra* note 128, at 15, 44; *see also* Notice of Regulatory Determination on Wastes from the Combustion of Fossil Fuels, 65 Fed. Reg. 32,214, 32,229–31 (2000) (codified at 40 C.F.R. pt. 261); U.S. EPA, REPORT TO CONGRESS: WASTES FROM THE COMBUSTION OF FOSSIL FUELS 3-1 (1999).

182 *See* COMM. ON COAL WASTE IMPOUNDMENTS, NAT'L RESEARCH COUNCIL, COAL WASTE IMPOUNDMENTS: RISKS, RESPONSES, AND ALTERNATIVES 17, 26–31 (2002); COMM. ON MINE PLACEMENT, *supra* note 128, at 3; SWEET, *supra* note 9, at 41. For examples of toxic discharges from solid coal refuse, see *United States v. Law*, 979 F.2d 977 (4th Cir. 1992), *cert. denied*, 507 U.S. 1030 (1993), and Clara Bingham, *Under Mined*, WASH. MONTHLY, Jan.–Feb. 2005, at 28.

183 *See* MORRIS, *supra* note 125, at 45–47.

184 *Id.* at 85 tbl.5.2, 86 tbl.5.3. Predicted cancer fatalities due to ionizing radiation from burning coal are ten times those due to nuclear power, but both are very low. *See* FINKELMAN & BUNNELL, *supra* note 161, at 12 tbl.9; *see also* MORRIS, *supra*, at 81–88.

185 RICHARD L. GARWIN & GEORGES CHARPAK, MEGAWATTS AND MEGATONS: THE FUTURE OF NUCLEAR POWER AND NUCLEAR WEAPONS 233 (2002). The Chernobyl explosion, discussed *infra*, Part II.C, is the only incident involving a

5. *Large-Scale Use of "Clean-Coal" Technology Is Decades Away*

Scientists and engineers believe that it is technologically possible to create a process for burning coal which creates no conventional air pollution and stores all of the potential carbon emissions in the earth's underground layers.[186] In 2003, such a proposal was part of the President's State of the Union speech,[187] and the coal industry has been talking about this idea without rushing to adopt it.[188]

Whether the needed carbon storage and sequestration will ever come about, however, is another question. The

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commercial nuclear power plant that has had significant environmental consequences. The well-known Three Mile Island accident did not result in serious ecological damage. CHARLES B. RAMSEY & MOHAMMAD MODARRES, COMMERCIAL NUCLEAR POWER: ASSURING SAFETY FOR THE FUTURE 105 (1998).

[186] *See* WARKENTIN-GLENN, *supra* note 3, at 177–78.

[187] *See* President George W. Bush, Address Before a Joint Session of the Congress on the State of the Union, 39 WEEKLY COMP. PRES. DOC. 109, 111 (Feb. 3, 2003). "Today I am pleased to announce that the United States will sponsor a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen powerplant." Statement Announcing the Hydrogen Powerplant Demonstration Project and the Carbon Sequestration Leadership Forum, 39 WEEKLY COMP. PRES. DOC. 253, 253–54 (Mar. 3, 2003). The Department of Energy announced that "[t]he prototype plant will establish the technical and economic feasibility of producing electricity and hydrogen from coal . . . while capturing and sequestering the carbon dioxide generated in the process . . . [relieving] environmental concerns associated with coal utilization." U.S. Dep't of Energy, FutureGen: Tomorrow's Pollution-Free Power Plant, http://www.fossil.energy.gov/programs/powersystems/futuregen/ (last visited Feb. 10, 2007). In his 2007 State of the Union address, President Bush said: "We must continue changing the way America generates electric power by even greater use of clean coal technology, solar and wind energy, and clean, safe nuclear power." *See* President George W. Bush, Address Before a Joint Session of the Congress on the State of the Union, 43 WEEKLY COMP. PRES. DOC. 57, 59 (Jan. 23, 2007). The reference to "even greater use of clean-coal technology" must refer to the minor improvements in emission reduction that have already taken place because "clean-coal technology," in the sense in which the term is commonly used throughout the world, is not currently being used in the United States at all. *See* IEA Clean Coal Centre: Clean Coal Technologies, http://www.iea-coal.org.uk/content/default.asp?PageId=62 (last visited Jan. 31, 2007) (listing the variety of clean coal technologies).

[188] Tim Appenzeller, *The Coal Paradox*, NAT'L GEOGRAPHIC, Mar. 2006, 96, 102–03. *See* Jonathan S. Martel et al., *The EPA's Tech Divide*, PUB. UTIL. FORT., June 2006, at 80. The so-called "FutureGen Project" will provide federal funding of up to $700,000,000 for construction of a prototype facility at one of four sites yet to be selected. Notice of Intent To Prepare an Environmental Impact Statement for Implementation of the FutureGen Project, 71 Fed. Reg. 42,840 (July 28, 2006).

Intergovernmental Panel on Climate Change has released an extensive study of the potential methods of carbon capture and storage.[189] They concluded that capturing carbon dioxide before it is released as power-plant emissions is possible but expensive with current technology.[190] Once captured, existing technologies can be used to inject the gas into underground layers, such as existing or depleted petroleum reservoirs.[191] But the risk of sudden escape of the injected gas needs to be evaluated; the release of large amounts of carbon dioxide into the atmosphere can asphyxiate all oxygen-dependent organisms enveloped by the cloud of carbon dioxide.[192]

In summary, coal mining and combustion adversely affects the natural environment in many ways, and the chances of seeing widespread use of technological innovations that will reduce these impacts within the next decade are negligible.

B. *Nuclear Power Has Much Less Effect on Ecological Systems than Coal*

Like coal, nuclear power is made from a mineral substance that comes from a mine, is transported to the power plant and removed from the plant when its usefulness has ended. The uranium used in nuclear power plants, however, has only a small fraction of the ecological impact of coal at any stage of its cycle, both in total effect and per unit of power produced. The nuclear industry claims that:

> Nuclear energy has perhaps the lowest impact on the environment—including air, land, water, and wildlife—of any energy source, because it does not emit harmful gases, isolates its waste from the environment, and requires less area to

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[189] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CARBON DIOXIDE CAPTURE AND STORAGE (Bert Metz et al. eds., 2005).

[190] *See id.* at 168–70; *see also* NAT'L COMM'N ON ENERGY POLICY, *supra* note 105, at 53 (carbon storage project development will require substantial research over the next ten to fifteen years). Carbon capture and storage for large power plants has not yet been implemented anywhere in the world. WORLD ENERGY OUTLOOK 2006, *supra* note 41, at 171.

[191] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *supra* note 189, at 6.

[192] "A concentration of CO_2 greater than 7–10% in air would cause immediate dangers to human life and health." *Id.* at 31. In 1986, approximately 1500 people died when carbon dioxide that had accumulated in Lake Nyos, Cameroon, erupted and formed a lethal cloud that asphyxiated people living along the shores of the lake. Boyce Rensberger, *Cameroon Lake Victims Died of Asphyxiation*, WASH. POST, Sept. 13, 1986, at A13.

produce the same amount of electricity as other sources.[193]

The evidence supports these claims, as will be shown below.[194] Moreover, the risk of a serious accident or terrorist attack on the next generation of nuclear plants will be slight.[195]

1. *The Amount of Uranium Used Is a Tiny Fraction of the Coal Used*

The mining of uranium admittedly can create some of the same adverse ecological impacts as the mining of coal.[196] The difference, however, is that while the coal-fired power plants in the United States used slightly over a billion *tons* of coal in 2005,[197] nuclear power plants used only 66 million *pounds* of uranium oxide.[198] Thus the scale of the impact from uranium mining is not in the same ball park as the impact of coal mining.[199] Virtually all uranium mines currently operating in the United States are underground mines or use the in situ leaching method,[200] which both have much less impact on the environment than open pit uranium mining.[201] Moreover, coal-fired power plants produce

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[193] Nuclear Energy Inst., Nuclear: The Clean Air Energy, http://www.nei.org/index.asp?catnum=1&catid=11 (last visited Feb. 10, 1007).

[194] See *infra* Part II.B.1–4.

[195] *See infra* Part II.B.5.

[196] S*ee e.g.*, *Blighted Homeland: A Peril that Dwelt Among the Navajos: During the Cold War, Uranium Mines Left Contaminated Waste Scattered Around the Indians*, L.A. TIMES, Nov. 19, 2006, at A1.

[197] ANNUAL ENERGY REVIEW 2005, *supra* note 27, at 205 tbl.7.1.

[198] Energy Info. Admin., Uranium Marketing Annual Report, http://www.eia.doe.gov/cneaf/nuclear/umar/umar.html (last visited Feb. 10, 2007).

[199] The OECD's current "Red Book," the recognized source of worldwide uranium data, estimates that the amount of known uranium available for mining economically at a price of $130 per kilogram is about 4.7 million metric tons. OECD NUCLEAR ENERGY AGENCY & INT'L ATOMIC ENERGY AGENCY, URANIUM 2005: RESOURCES, PRODUCTION, AND DEMAND 9 (2006). The amount of recoverable coal available for mining in the world is estimated at 997,506 million short tons. ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, WORLD ESTIMATED RECOVERABLE COAL (MILLION SHORT TONS) (2006), http://www.eia.doe.gov/pub/international/iea2004/table82.xls. Over 1131 million short tons of coal were mined in the United States in 2005. ANNUAL COAL REPORT 2005, *supra* note 126, at 17 tbl.2.

[200] Energy Info. Admin., U.S. Uranium Mine Production and Number of Mines and Sources, http://www.eia.doe.gov/cneaf/nuclear/dupr/umine.html (last visited Feb. 10, 2007).

[201] World Nuclear Ass'n, Environmental Aspects of Uranium Mining, http://www.world-nuclear.org/info/inf25.html (last visited Feb. 10, 2007).

half the electricity in the United States while nuclear power plants produce one-fifth.[202]

In addition, unlike coal, uranium used in power plants can be recycled and used again.[203] At the present time, the United States does not reprocess its nuclear fuel,[204] but countries such as Great Britain, France, Japan, and Russia do so on a regular basis.[205] The policy issues related to reprocessing are beyond the scope of this article, but it should be noted that the possibility of future reprocessing further reduces the slim risk that supplies of uranium will run out,[206] despite the fact that the known uranium resources would provide enough fuel to support four times the current amount of worldwide nuclear electricity generation for the next 80 years.[207] Furthermore, uranium is not the only element that can be used as nuclear fuel; India is producing nuclear fuel from thorium, of which it has ample supplies.[208]

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202 ELECTRIC POWER ANNUAL 2005, *supra* note 43, at 1 fig.ES1.

203 *See* BODANSKY, *supra* note 2, at 214–18; SCOTT W. HEABERLIN, A CASE FOR NUCLEAR-GENERATED ELECTRICITY 300–05 (2004).

204 *See* BODANSKY, *supra* note 2, at 216. In the Energy Policy Act of 2005, Congress authorized further study of reprocessing. *See* Energy Policy Act of 2005, Pub. L. No. 109-58, § 953, 119 Stat. 594, 886 (2005) (to be codified at 42 U.S.C. § 16273); Eli Kintisch, *Congress Tells DOE to Take Fresh Look at Recycling Spent Reactor Fuel*, 310 SCI. 1406 (2005). The administration has been consulting with other countries, including Japan and Russia, about forming a Global Nuclear Energy Partnership to ship spent fuel to the United States for recycling. The recycling is still in the development stage, but the plan is to build a prototype plant at the Department of Energy's (DOE's) Savannah River facility. *See* Peter Baker & Dafna Linzer, *Nuclear Energy Plan Would Use Spent Fuel*, WASH. POST, Jan. 26, 2006, at A1.

205 *See* Emma Marris, *Nuclear Reincarnation*, 441 NATURE 796, 797 (2006); BODANSKY, *supra* note 2, at 216–17.

206 *See* BODANSKY, *supra* note 2, at 225–27; MORRIS, *supra* note 125, at 168; *see also Uranium: Glowing*, ECONOMIST, Aug. 19, 2006, at 53.

207 BODANSKY, *supra* note 2, at 225. Furthermore, "[u]ranium resources are widely distributed around the world." WORLD ENERGY OUTLOOK 2006, *supra* note 41, at 377.

208 PETER E. HODGSON, NUCLEAR POWER, ENERGY AND THE ENVIRONMENT 59 (1999).

2. *Nuclear Power Plants Cause No Air or Radiation Pollution*

Whereas coal burning creates large amounts of sulfur dioxide and nitrogen oxides, nuclear power generation emits none.[209] The reason that nuclear power plants produce no air pollutants when generating power is that in a nuclear power plant, nothing is burned; the heat used to spin the turbines and drive the generators comes from the natural decay of the radionuclides in the fuel.[210] It is the burning of fossil fuels, and particularly coal, that causes air pollution from electric power plants.[211]

Nor does a nuclear power plant pollute its surroundings with dangerous radiation, as its opponents often imply.[212] The population exposure from the normal operation of nuclear power plants is far lower than exposure from natural sources.[213] "The civilian nuclear power fuel cycle, involving mining, fuel fabrication, and reactor operation, contributes a negligible dose [of radiation] to the general public."[214] Life cycle air pollutant emissions from nuclear plants are comparable to those of the wind, solar, and hydro facilities—in other words, minimal.[215]

Concern is sometimes raised about the possibility of releases of large amounts of radiation from an accident at a nuclear power plant.[216] In the four decades of commercial power plant operation

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209 LARRY FOULKE & H. STERLING BURNETT, NAT'L CTR. FOR POLICY ANALYSIS, BURNING BRIGHT: NUCLEAR ENERGY'S FUTURE 1–2 (2005), http://www.ncpa.org/pub/ba/ba511/ba511.pdf.

210 *See* EPA, Clean Energy: Glossary, http://www.epa.gov/cleanrgy/glossary.htm (last visited Feb. 10, 2007) (defining "Nuclear Energy").

211 *See supra* Part II.A.2–4.

212 *See* MORRIS, *supra* note 125, at 81–87.

213 "[P]eople who live right at the fence line of a nuclear power plant only receive about one-fifteenth as much radiation as they get from nature." MORRIS, *supra* note 125, at 40; *see also* CALDICOTT, *supra* note 5, at 46; GARWIN & CHARPAK, *supra* note 185, at 106.

214 BODANSKY, *supra* note 2, at 79.

215 Nuclear Energy Inst., Life-Cycle Emissions Analysis, http://www.nei.org/index.asp?catnum=2&catid=260 (last visited Feb. 10, 2007) (describing "life-cycle" analysis as including mining, transportation, plant construction, etc.); *see also* W. KREWITT ET AL., EUROPEAN COMM'N, EXTERNE NATIONAL IMPLEMENTATION: GERMANY 39 (1998), http://externe.jrc.es/ger.pdf.

216 *See, e.g.*, NAT'L RESEARCH COUNCIL, ALTERNATIVES TO THE INDIAN POINT ENERGY CENTER FOR MEETING NEW YORK ELECTRIC POWER NEEDS, at vii (2006) (noting the concern currently being expressed by some people living near the Indian Point plant in the Hudson Valley).

in the United States, such a release has never occurred.[217] The only serious accident at a commercial nuclear reactor in the United States caused no radiation damage to people outside the plant and little environmental damage.[218]

3. *No Greenhouse Gases Are Emitted by Nuclear Power Plants*

The use of nuclear fuel to generate electricity causes no emissions of greenhouse gases.[219] As of 2003, nuclear power accounted for 69% of the carbon-free generation in the United States.[220] Even if the full life cycle of a nuclear power plant is calculated, the emissions of greenhouse gases are negligible.[221] The avoidance of greenhouse gas emissions has been a major factor in converting some prominent environmentalists to the

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[217] *See* BODANSKY, *supra* note 2, at 371–72, 411–14.

[218] *See id.* at 417–19. In 1979, at the Three Mile Island (TMI) plant near Harrisburg, Pennsylvania, a combination of equipment failure and poor communications caused operators to allow one of TMI's reactors to lose cooling water. The fuel overheated and radioactive water escaped from the reactor enclosure into an adjoining building, but no significant amount of radiation escaped into the surrounding environment. *See id.* at 414–19; *see also In re* TMI Litig., 193 F.3d 613, 656–58 (3d Cir. 1999). For a complete history of the TMI accident, see J. SAMUEL WALKER, THREE MILE ISLAND: A NUCLEAR CRISIS IN HISTORICAL PERSPECTIVE (2004). Although the accident exceeded the design basis of the plant, "the defense-in-depth philosophy of a reactor plant (i.e., the concept of multiple barriers) prevented any significant harm to the public or the operators." GEOFFREY F. HEWITT & JOHN G. COLLIER, INTRODUCTION TO NUCLEAR POWER 160 (2d ed. 2000).

[219] *See* NAT'L COMM'N ON ENERGY POLICY, *supra* note 105, at 57; *see also* MASS. INST. OF TECH., *supra* note 9, at 18.

[220] NAT'L COMM'N ON ENERGY POLICY, *supra* note 105, at 57 fig.4-10.

[221] Energy analyst Vaclav Smil says that:

> [E]ven when the full energy chain is evaluated nuclear generation produces only about [9 grams of CO_2 per kilowatt-hour]. . . . If all of the electricity generated by nuclear plants was to be produced by burning coal, the world's CO_2 emissions would rise by . . . an equivalent of more than one-third of the total produced by fossil fuel combustion in the year 2000.

SMIL, *supra* note 16, at 313; *see also* IAN HORE-LACY, *External Costs—Environment, Health and Safety Issues*, *in* NUCLEAR ELECTRICITY 6-4 fig.17 (7th ed. 2003), *available at* http://www.uic.com.au/ne.htm. *But see* JAN WILLEM STORM VAN LEEUWEN & PHILIP SMITH, NUCLEAR POWER; THE ENERGY BALANCE (2005), http://www.stormsmith.nl/ (arguing that nuclear power produces a significant amount of carbon dioxide); World Nuclear Ass'n, Energy Analysis of Power Systems , http://www.world-nuclear.org/info/printable_information_papers/inf11print.htm (last visited Mar. 14, 2007) (critiquing Jan Willem Storm van Leeuwen and Philip Smith).

support of new nuclear reactor construction.[222]

Many companies in the United States now recognize the need to factor in the potential cost of complying with future greenhouse gas regulations in evaluating power plant proposals,[223] and some of the countries that have agreed to comply with the Kyoto protocol on the reduction of greenhouse gas emissions are looking at nuclear power as a way to facilitate compliance.[224]

4. *Dry Cask Storage Is a Safe Way to Store Spent Fuel*

In the United States, one of the most common arguments against nuclear power relates to the current proposal to bury spent fuel from power plants in a permanent storage facility at Yucca Mountain, Nevada.[225] In my opinion, resolution of this debate is really unnecessary for the construction of new nuclear power plants because recent studies have shown that dry cask storage is a safe and secure method of handling spent fuel for the next century.[226] Dry casks are designed to cool the spent fuel to prevent temperature elevation from radioactive decay and to shield the

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222 *See* Felicity Barringer, *Old Foes Soften to New Reactors*, N.Y. TIMES, May 15, 2005, at 1; Nuclear Energy Inst., Prominent Environmentalists Support Nuclear Energy, http://www.nei.org/index.asp?catnum=2&catid=322 (last visited Feb. 10, 2007); *see also* CALDICOTT, *supra* note 5, at xii (listing some environmentalists who support nuclear power).

223 *See supra* note 78 and accompanying text. For current information on Congressional consideration of legislation that may impose additional costs on power plants that emit greenhouse gasses, see Pew Ctr. On Global Climate Change, 109th Congress Proposals, http://www.pewclimate.org/what_s_being_done/in_the_congress/109th.cfm (last visited Feb. 10, 2007). The International Energy Agency estimates that "A price of about $10 per tonne of CO_2 emitted makes nuclear competitive with coal-fired power stations, even under the higher construction cost assumption." WORLD ENERGY OUTLOOK 2006, *supra* note 41, at 345.

224 *See, e.g.*, *Britain: Blair Urges New Nuclear Plants*, N.Y. TIMES, May 17, 2006, at A8. The British government has released a report saying that the economic benefits of actions to combat climate change will substantially exceed the costs. NICOLAS STERN, STERN REVIEW: THE ECONOMICS OF CLIMATE CHANGE (2006), *available at* http://www.hm-treasury.gov.uk/media/9A2/80/Ch_1__Science.pdf

225 *See, e.g.*, Nuclear Energy Inst. v. EPA, 373 F.3d 1251 (D.C. Cir. 2004) (challenging the statutory and regulatory scheme that provided for the federal nuclear waste repository at Yucca Mountain); *see also* BODANSKY, *supra* note 2, at 291–332 (describing the site and plans related to the Yucca Mountain Repository).

226 *See* NAT'L RESEARCH COUNCIL, PUBLIC REPORT: SAFETY AND SECURITY OF COMMERCIAL SPENT NUCLEAR FUEL STORAGE 67–69 (2006); SWEET, *supra* note 9, at 189–90.

cask's surroundings from radiation without the use of water or mechanical systems. Heat is released by conduction through the solid walls of the cask (typically made of concrete, lead, steel, polyethylene, and boron-impregnated metals or resins) and by natural convection or thermal radiation. The cask walls also shield the surroundings from radiation.[227] Spent fuel is usually kept in pools for five years before storage in dry casks in order to reduce decay heat and inventories of radionuclides.[228] As the bipartisan National Commission on Energy Policy recently explained, dry cask storage "is a proven, safe, inexpensive waste-sequestering technology that would be good for 100 years or more, providing an interim, back-up solution against the possibility that Yucca Mountain is further delayed or derailed—or cannot be adequately expanded before a further geologic repository can be ready."[229]

At present, most spent fuel is initially stored in water-filled pools on each nuclear power plant site.[230] After five years, the fuel has cooled enough to be transferred to dry casks for storage, and many plants have built such casks onsite.[231] The National Research Council has pointed out that the temporary storage of spent fuel in a retrievable form, such as dry cask storage, might provide opportunities for re-use of the material if new ways of using it were developed in the future.[232] In any event, the current availability of dry cask storage means that the problem of spent fuel no longer appears to be an insurmountable barrier to building new nuclear plants.

[227] NAT'L RESEARCH COUNCIL, *supra* note 226, at 61.

[228] *Id.* at 61, 70.

[229] NAT'L COMM'N ON ENERGY POLICY, *supra* note 105, at 58.

[230] *See* NAT'L RESEARCH COUNCIL, *supra* note 226, at 38; *see also* BODANSKY, *supra* note 2, at 254.

[231] *See* SWEET, *supra* note 9, at 190; BODANSKY, *supra* note 2, at 255–57; NAT'L RESEARCH COUNCIL, *supra* note 226, at 61, 70.

[232] *See generally* NAT'L RESEARCH COUNCIL, ONE STEP AT A TIME: THE STAGED DEVELOPMENT OF GEOLOGIC REPOSITORIES FOR HIGH-LEVEL RADIOACTIVE WASTE, 7, 130 (2003) (noting the potential for an increased focus on how to retrieve spent fuel); NAT'L RESEARCH COUNCIL, NUCLEAR WASTES: TECHNOLOGIES FOR SEPARATIONS AND TRANSMUTATION 7, 124 (1996) (predicting an increasing interest in uranium reprocessing and noting that the Department of Energy is seeking to use dry cask storage for storing retrievable spent fuel); Patricia A. Baisden, *A Renaissance for Nuclear Power?*, *in* ENERGY AND TRANSPORTATION: CHALLENGES FOR THE CHEMICAL SCIENCES IN THE 21ST CENTURY 49, 52 (2003), *available at* http://books.nap.edu/catalog/10814.html (discussing potential new technologies to recycle nuclear fuel).

5. *Significant Releases of Radiation Caused by Terrorist Attacks or Accidents at Modern Nuclear Power Plants Are Highly Unlikely*

Terrorists could not acquire bomb-making material from spent fuel in a nuclear power plant, because the material would be too radioactive for them to handle.[233] Nor would it be feasible to bomb an American reactor in a way that would release deadly radiation.[234] All reactors in American power plants are contained in structures made of heavy steel and concrete three to four feet thick,[235] and the reactor pressure vessel itself is further protected by steel walls eight inches thick.[236] The robust construction of nuclear power plants would provide substantially more protection against assault with airplanes or other types of weapons than exists at "other critical infrastructure such as chemical plants, refineries, and fossil-fuel-fired electrical generating stations."[237] Attacking a plant by crashing an airplane into it would be difficult because the reactor is a small, low structure often surrounded by large but harmless cooling towers.[238] Even an attempt to hit a reactor with a large airliner would be unlikely to succeed in releasing radiation, with success depending on the attacker's "unpredictable 'good fortune.'"[239]

Legitimate concerns have been raised that some (but not all) existing nuclear power plants have spent fuel storage pools in locations that might be susceptible to a terrorist attack that could drain the water from the pool, which might cause a release of radiation if the water was not quickly replaced.[240] The Nuclear Regulatory Commission has issued new regulations to protect against this possibility,[241] and designers of newly-constructed

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[233] *See* BODANSKY, *supra* note 2, at 492–501; Baisden, *supra* note 232, at 50.

[234] *See* SWEET, *supra* note 9, at 190.

[235] MORRIS, *supra* note 125, at 140.

[236] *See id.* at 141.

[237] NAT'L RESEARCH COUNCIL, *supra* note 226, at 47.

[238] *See* BODANSKY, *supra* note 2, at 512.

[239] *See id.*

[240] *See* CALDICOTT, *supra* note 5, at 99–104; NAT'L RESEARCH COUNCIL, *supra* note 226, at 38.

[241] As required by the Energy Policy Act of 2005, the Nuclear Regulatory Commission has issued a new proposed "Design Basis Threat" rule to "redefine the level of security requirements" at nuclear power plants. 70 Fed. Reg. 67,380 (proposed Nov. 7, 2005) (to be codified at 10 C.F.R. pt. 73); *see also* Power Reactor Security Requirements, 71 Fed. Reg. 62,664 (proposed Oct. 26, 2006) (to be codified at 10 C.F.R. pts. 50, 72, 73). An appeals court has held that the

power plants are now aware of this potential problem and will avoid it.[242]

Insofar as the risk of accidents is concerned, few industries—and certainly not the coal industry—have a safety record as exemplary as the nuclear power industry.[243] The operation of U.S. nuclear power plants has proven to be very safe; the National Commission on Energy Policy has affirmed that "experience with nuclear power plants over the past decade and more, in the United States and elsewhere, has demonstrated that these plants can be operated with high degrees of reliability and safety and extremely low exposures of workers and public radiation."[244]

The same can be said of power plants elsewhere in the world, except in the Soviet Union. University of Washington nuclear physicist David Bodansky states that "[f]or commercial reactors in the non-Soviet world, which account for the largest part of the reactor experience, the safety record is excellent."[245] At no such power plant has an accident "caused the known death of any nuclear plant worker from radiation exposure or . . . exposed any member of the general public to a substantial radiation dose."[246]

C. *"But What About Chernobyl?"*

In 1986, an explosion at the Chernobyl nuclear power plant in the Ukraine caused the release of large amounts of radiation into the atmosphere.[247] Initially, the Soviet government released little information about the explosion and tried to play down its seriousness, but this secrecy caused great nervousness throughout Europe, and fed the public's fears of nuclear power all over the

possibility of terrorist attacks on nuclear facilities is an issue that should be discussed in reviews under the National Environmental Policy Act. San Luis Obispo Mothers for Peace v. Nuclear Regulatory Commission, 449 F.3d 1016, 1031, 1035 (9th Cir. 2006) ("We find it difficult to reconcile the Commission's conclusion that, as a matter of law, the possibility of a terrorist attack on a nuclear facility is 'remote and speculative,' with its stated efforts to undertake a 'top to bottom' security review against this same threat.").

242 *See* NAT'L RESEARCH COUNCIL, *supra* note 226, at 38–59 (explaining the potential risks to storage pools); *Nuclear Power: The Shape of Things to Come*, ECONOMIST, June 3, 2006, at 77 (explaining efforts to design nuclear reactors that will address known safety issues).

243 *See, e.g.*, Moore, *supra* note 21.

244 NAT'L COMM'N ON ENERGY POLICY, *supra* note 105, at 58.

245 BODANSKY, *supra* note 2, at 371.

246 *Id.*

247 *Id.* at 425.

world.[248] Now a comprehensive analysis of the event and its aftermath has been made: In 2005, a consortium of United Nations agencies called the Chernobyl Forum released its analysis of the long-term effects of the Chernobyl explosion.[249]

The U.N. agencies' study found that the explosion caused fewer deaths than had been expected.[250] Although the Chernobyl reactor was poorly designed and badly operated[251] and lacked the basic safety protections found outside the Soviet Union,[252] fewer than seventy deaths so far have been attributed to the explosion, mostly plant employees and firefighters who suffered acute radiation sickness.[253] The Chernobyl reactor, like many Soviet reactors, was in the open rather than in an American type of pressurizable containment structure, which would have prevented the release of radiation to the environment if a similar accident had occurred.[254]

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[248] *Id.* at 434–36.

[249] *See* CHERNOBYL FORUM, CHERNOBYL'S LEGACY (2d rev. version 2006), *available at* http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf.

[250] *See id.* at 14–21.

[251] *See* MORRIS, *supra* note 125, at 128–29.

[252] *See* BODANSKY, *supra* note 2, at 422–23; SWEET, *supra* note 9, at 184–86. For a history of the Soviet nuclear power program, and a critique of the safety of RBMK reactors, see DAVID R. MARPLES, CHERNOBYL AND NUCLEAR POWER IN THE USSR 95–114 (1986). For an interesting comparison of TMI and Chernobyl, see WALKER, *supra* note 218, at 237–39.

[253] CHERNOBYL FORUM, *supra* note 249, at 14–16. It is estimated that four to six thousand people living in the area may develop and die from cancer as a result of the accident, but these deaths have not yet occurred. *Id.* Residents were evacuated from an area of 3000 square kilometers, and all agricultural activities and transfers of products from this "exclusion zone" were banned in order to minimize consumption of contaminated food. Although parts of the exclusion zone have been reopened to various degrees, the harvesting of crops, game, and forest products is still restricted, so relatively few people have returned. *See* MARY MYCIO, WORMWOOD FOREST: A NATURAL HISTORY OF CHERNOBYL 23, 231–33 (2005). The U.N. study found that the only other convincing evidence of radiation-induced disease was thyroid cancer, which affected some four to five thousand of those children in the immediate area. Thyroid cancer is treatable, and as of 2002 only 15 of these children had died from the disease. CHERNOBYL FORUM, *supra* note 249, at 16–20.

[254] *See* BODANSKY, *supra* note 2, at 185. The accident did not take place during normal operation of the reactor, but during "a mangled and ill-advised experiment that violated every rule in the plant's own safety book [in which] the pumps that powered Chernobyl's emergency water cooling systems were deliberately shut down." MYCIO, *supra* note 253 at 13; *see also* SWEET, *supra* note 9, at 184–87 (proposing that if such an experiment had been attempted in a light-water reactor of the type used outside of the Soviet Union, the reactor

Perhaps the most surprising finding of the U.N. agencies' study was that "the ecosystems around the Chernobyl site are now flourishing. The [Chernobyl exclusion zone] has become a wildlife sanctuary, and it looks like the nature park it has become."[255] Jeffrey McNeely, the chief scientist of the World Conservation Union, has made similar observations:

> Chernobyl has now become the world's first radioactive nature reserve. . . . 200 wolves are now living in the nature reserve, which has also begun to support populations of reindeer, lynx and European bison, species that previously were not found in the region. While the impact on humans was strongly negative, the wildlife is adapting and even thriving on the site of one of the 20th century's worst environmental disasters.[256]

Mary Mycio, the Kiev correspondent for the Los Angeles Times, has written a fascinating book based on her many visits to the exclusion zone and interviews with people in the area.[257] She notes that the fear that radiation would produce permanent deformities in animal species has not been borne out after twenty years; the population and diversity of animals in even some of the most heavily radiated parts of the exclusion zone is similar to comparable places that are less radioactive.[258]

How is it possible that one of the most horrendous mishaps in human history had so few adverse effects on the natural environment? The answer requires a brief discussion of both

would have shut itself down, rather than causing the nuclear fuel to explode, releasing radiation into the atmosphere).

255 CHERNOBYL FORUM EXPERT GROUP "ENVIRONMENT," INT'L ATOMIC ENERGY AGENCY, ENVIRONMENTAL CONSEQUENCES OF THE CHERNOBYL ACCIDENT AND THEIR REMEDIATION: TWENTY YEARS OF EXPERIENCE 137 (2006) (citation omitted), *available at* http://www-pub.iaea.org/MTCD/publications/PDF/Pub1239_web.pdf.

256 JEFFREY A. MCNEELY, WORLD CONSERVATION UNION, ENERGY AND BIODIVERSITY: UNDERSTANDING COMPLEX RELATIONSHIPS 4 (2003), *available at* http://webdomino1.oecd.org/comnet/agr/BiomassAg.nsf/viewHtml/index/$FILE/McNeelyIUCN.pdf.

257 MYCIO, *supra* note 253.

258 *See id.* at 118–19. Opponents of nuclear power claim that the "diabolical elements" produced by nuclear fission will "inevitably . . . enter the reproductive organs of plants, animals, and humans, where they will mutate the genes in reproductive cells to cause disease and death in the immediate generation or pass a genetic disease to distant offspring down the time track." *See, e.g.*, CALDICOTT, *supra* note 5, at 41. But they cite no evidence that any nuclear power plant, even Chernobyl, has had such an effect. LOVELOCK, *supra* note 73, at 91, 95.

radioactivity and ecology.

1. *Nuclear Energy Is a Natural Form of Energy*

Radioactivity plays an important role in the natural environment of the earth.[259] Radionuclides, like the other elements, were formed primarily in the evolution and explosion of stars.[260] Nuclear fission happens naturally and spontaneously in radioactive elements contained in the earth. This naturally occurring nuclear fission is what maintains the warmth of the earth's interior, keeping the tectonic plates in motion, causing mountains to rise up, and driving a variety of other natural processes.[261] In fact "'the energy involved in almost all natural processes can be traced to nuclear reactions and transformations.' Fusion is the principal source of the sun's heat, and fission is the principal source of the earth's . . ."[262]

All animals, including humans, are continually exposed to natural sources of radiation. "Each second, about 15,000 particles of radiation strike each and every one of us." It comes from naturally radioactive elements in the rocks and soil, from food grown in such soil, and from the cosmic rays from space.[263] Radiation doses from the normal operation of the nuclear fuel cycle are very small compared to natural background radiation.[264] Scientists generally agree that the public's fear of low doses of radiation is far greater than their fear of much more serious risks.[265]

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[259] *See* E.C. PIELOU, THE ENERGY OF NATURE 139–48 (2001). Geothermal energy, a highly desirable resource in the few places where it is available, is generated by radioactive material in the Earth. LOVELOCK, *supra* note 73, at 68.

[260] BODANSKY, *supra* note 2, at 66–73.

[261] *See* PIELOU, *supra* note 259, at 140–47. The dramatic events that surrounded the first "atom bomb" may have led people to think that nuclear energy was a human creation, but the radioactive properties of radium and uranium have been known since the late 19th century. *See* BODANSKY, *supra* note 2, at 57–58 (noting that natural radioactivity provides a benchmark against which to measure the significance of man-made radioactivity and that radioactive properties of radium and uranium have been known since the late 19th century).

[262] PIELOU, *supra* note 259, at 141 (footnote omitted).

[263] MORRIS, *supra* note 125, at 82.

[264] BODANSKY, *supra* note 2, at 92; *see also* RICHARD WOLFSON, NUCLEAR CHOICES: A CITIZEN'S GUIDE TO NUCLEAR TECHNOLOGY 184 (rev. ed. 1993).

[265] *See, e.g.*, STEVEN BREYER, BREAKING THE VICIOUS CIRCLE: TOWARD EFFECTIVE RISK REGULATION 21 tbl.4 (1993); MORRIS, *supra* note 125, at 80–88.

2. *Ecological Systems Have Evolved to Adapt to Disturbance*

Natural radiation is a slow and steady process. How can it be that an explosion that speeds up and magnifies this process immensely can have had so little long-range impact on ecological systems and processes?

Ecologists today recognize that disturbance is a natural part of ecological processes. Ecological change caused by disturbance is not only inevitable but, within limits, necessary if ecological processes are to be maintained. This current view is a departure from much of the earlier ecological thinking, which assumed that each part of the world had a "climax" condition that in the aggregate created a static "balance of nature."[266] University of Illinois wildlife law expert Eric Freyfogle summarizes the importance of this change: "Ecologists now realize that the whole concept of community climax is misleading, for climaxes are always tentative and subject to being upset by a wide variety of natural forces, including fire, disease, and weather."[267]

My colleague, Dan Tarlock, has chronicled how the science of "nonequilibrium" ecology emphasizes the important role that disturbance, such as wildfire, flood, or epidemic, plays in ecological processes.[268] Things our society has called "disasters" are not external to the ecological system but a vital part of it.[269] Disturbance can be seen as an inevitable ecological process and a

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[266] The idea of a balance of nature was promoted by Linnaeus. Issac J. Biberg, *The Economy of Nature*, *in* MISCELLANEOUS TRACTS RELATING TO NATURAL HISTORY HUSBANDRY AND PHYSICK 37 (Lucille Maiorca ed., Benjamin Stillingfleet trans., Arno Press 1977) (Carl Linnaeus ed., 1749); *see also* ALDO LEOPOLD, A SAND COUNTY ALMANAC (1949).

[267] ERIC T. FREYFOGLE, JUSTICE AND THE EARTH: IMAGES FOR OUR PLANETARY SURVIVAL 129–30 (1993).

[268] *See* A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121 (1994); *see also* Jonathan Baert Wiener, *Beyond the Balance of Nature*, 7 DUKE ENVTL. L. & POL'Y F. 1 (1996). Steward T.A. Pickett and P.S. White produced the pioneering synthesis of the important role of disturbance in ecology in 1985. S.T.A. Pickett & P.S. White, *Patch Dynamics: A Synthesis*, *in* THE ECOLOGY OF NATURAL DISTURBANCE AND PATCH DYNAMICS 371 (S.T.A. Pickett & P.S. White eds., 1985).

[269] *See, e.g.*, Anthony W. King, *Hierarchy Theory: A Guide to System Structure for Wildlife Biologists*, *in* WILDLIFE AND LANDSCAPE ECOLOGY: EFFECTS OF PATTERN AND SCALE 185, 208 (John A. Bissonette ed., 1997) (suggesting that occasional collapse of a population may be found normal if viewed from a long time frame).

stabilizing factor that needs to be understood,[270] and "[e]fforts to freeze or restore a static, pristine state" of nature are inappropriate "irrespective of whether the motive is to conserve nature, to exploit a resource for economic gain, to sustain recreation, or to facilitate development."[271]

From an ecological point of view, is Chernobyl really different than a "natural disaster"? I am certainly not trying to make excuses for the gross negligence that led to Chernobyl,[272] nor to minimize the enormous economic cost and human disruption caused by the accident, but I doubt that natural systems really react differently because the disturbance is caused by humans rather than a naturally-occurring hurricane or forest fire. Science has not found some perceptive ability of natural systems to distinguish disturbance caused by humans from natural disturbance: "Human activity not only causes new disturbances and disturbances that mimic and/or modify the effects of natural disturbance, but it also alters the frequency, intensity, and duration of 'natural' disturbance to the point that the dichotomy becomes artificial."[273]

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[270] R.V. O'NEILL ET AL., A HIERARCHICAL CONCEPT OF ECOSYSTEMS 163–69 (1986).

[271] C. S. Holling & Lance H. Gunderson, *Resilience and Adaptive Cycles*, *in* PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS 25, 31 (Lance H. Gunderson & C. S. Holling eds., 2002); *see also* Lovejoy & Hanna, *supra* note 114, at 393 (forcing greenhouse gas levels down too far might be adverse to biodiversity because it would require species to shift their range twice).

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> Chernobyl, while an accident in the sense that no one intentionally set it off, was also the deliberate product of a culture of cronyism, laziness, and a deep-seated indifference toward the general population. The literature on the subject is pretty unanimous in its opinion that the Soviet system had taken a poorly designed reactor and then staffed it with a group of incompetents. It then proceeded, as the interviews in this book attest, to lie about the disaster in the most criminal way.

Keith Gessen, *Translator's Preface* to SVETLANA ALEXIEVICH, VOICES FROM CHERNOBYL, at vii, ix (Keith Gessen trans., Dalkey Archive Press 2005) (1997).

[273] Bruce A. Hungate et al., *Disturbance and Element Interactions*, *in* INTERACTIONS OF THE MAJOR BIOGEOCHEMICAL CYCLES: GLOBAL CHANGE AND HUMAN IMPACTS, *supra* note 157, at 47, 58–59.

3. *Coal Combustion Injures Ecosystems More than Nuclear Accidents*

The study of the ecological impact of the Chernobyl experience should cause us to compare that terrible disturbance to the more gradual and less dramatic changes that humans are causing by burning coal. Explosions, even huge ones, are one-time events. Ecological processes have a long history of adapting to such events and recovering, as they have in the area around Chernobyl. But incremental changes of a unidirectional nature, which go on and on at rates faster than the kinds of change to which ecological processes have adapted, such as acid rain, mercury emissions, and climate change, may be the most serious threat to ecological systems and processes.[274] Ecological systems can be "metastable" if irregular disturbances at a particular scale are within the level of resilience of the system, thus allowing the system to remain relatively stable at a larger scale.[275] But disturbances that are continually pushing ecological systems in the same direction, as in the case of the disturbances that cause climate change, are likely to exceed the boundaries of metastability.[276] The "excess carbon dioxide we put in the atmosphere today is removed exceedingly slowly, meaning that the carbon dioxide we emit in the next half-century will alter the climate for millennia to come."[277]

Many biologists and ecologists today are more concerned about the impacts of climate change than about threats of nuclear accidents;[278] British scientist James Lovelock has written:

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[274] I have discussed these issues extensively in an earlier article. Fred Bosselman, *What Lawmakers Can Learn from Large Scale Ecology*, 17 J. LAND USE & ENVTL. L. 207, 288–94 (2002).

[275] "As long as the landscape system oscillates around a central position, it is in a metastable equilibrium." RICHARD T.T. FORMAN & MICHEL GODRON, LANDSCAPE ECOLOGY 431 (1986); *see also* Jianguo Wu & Orie L. Loucks, *From Balance of Nature to Hierarchical Patch Dynamics: A Paradigm Shift in Ecology*, 70 Q. REV. BIOLOGY 439 (1995).

[276] *See, e.g.*, Robert V. O'Neill, *Is It Time to Bury the Ecosystem Concept?* 82 ECOLOGY 3275, 3281–82 (2001).

[277] R.T. Pierrehumbert, *Climate Change: A Catastrophe in Slow Motion*, 6 CHI. J. INT'L L. 573, 577 (2006).

[278] *See, e.g.*, Moore, *supra* note 21; CLIMATE CHANGE AND BIODIVERSITY, *supra* note 114; SWEET, *supra* note 9, at 205; *see also* EUGENE LINDEN, THE WINDS OF CHANGE: CLIMATE, WEATHER AND THE DESTRUCTION OF CIVILIZATIONS 265–69 (2006).

> I am a green and would be classed among them, but I am most of all a scientist; because of this I entreat my friends among greens to reconsider . . . their wrongheaded objection to nuclear energy. Even if they were right about its dangers, and they are not, its use as a secure, safe and reliable source of energy would pose a threat insignificant compared with the real threat of intolerable and lethal heatwaves and sea levels rising to threaten every coastal city of the world.[279]

If we were to assume that nuclear power would produce a Chernobyl every thirty years, a highly improbable assumption, I believe we would do much less damage to ecological systems than is resulting from the ecological damage caused in large part by the burning of coal.

CONCLUSION

I have argued that the next decade's need for reliable base-load electrical generation in the United States will be solved by building either nuclear power plants or coal-fired power plants; the unreliability of natural gas supplies and prices, and the intermittent nature of current renewable resources, make them unsuitable for base-load needs. The extent to which a significant share of this new generation will be nuclear depends on a wide range of factors, only one of which—ecological impact—is discussed in this article. Insofar as that factor is concerned, however, the evidence overwhelmingly favors nuclear power over coal, and I hope that this will be recognized and taken into consideration. But I am making no prediction as to how important nuclear power will become, because any student of the history of energy knows that all forecasts always seem to be wrong.[280]

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[279] LOVELOCK, *supra* note 73, at 11.

[280] *See* SMIL, *supra* note 16, at 121 ("[F]or more than 100 years long-term forecasts of energy affairs . . . have had, save for a few proverbial exceptions confirming the rule, a manifest record of failure."); *see also* ROBERT J. DUFFY, NUCLEAR POLITICS IN AMERICA: A HISTORY AND THEORY OF GOVERNMENT REGULATION 228 (1997) (noting the remarkable instability of nuclear power institutions and policy); BODANSKY, *supra* note 2, at 53–54 (discussing past predictions that were rife with errors); Richard D. Cudahy, *The Choice of Fuel in Competitive Generation*, PUB. UTIL. FORT., June 15, 1995, at 31 (discussing predictions in the 1970s of widespread and cheap nuclear power).