

# POWER FUTURE

STEVEN FERREY†

I have been given opportunity to talk about the future of energy, and particularly electric energy and its impact on the environment. What a great topic! The way we choose to use energy is by far the single decision(s) that exerts the most profound and long-lasting impact on the environment. It is worth special emphasis that how we use energy is a choice, and there are alternatives today to the choices we have traditionally made. Electric energy, in particular, is extremely important because it is a premium-level energy carrier,<sup>1</sup> and one of the most significant sources of pollution to the environment.<sup>2</sup> DELPF is to be congratulated for focusing attention on it with this symposium.

The important environmental events of our future are not so much “trends” that are ineluctable, as they are “pivot points.” By that, I mean points in time and space at which the decisions we make on energy—consciously and unconsciously—will shape and form the very structure and elements of society. We have come through such “pivot points” in the past and today live with the directions and technologies then chosen.

We all know too well the costs of unconscious decisions. The emission of carbon into the atmosphere from the burning of fossil fuels in electric power plants, as well as internal combustion engines, poses one of the most serious global environmental challenges of this

---

† Professor of Law, Suffolk University Law School, Boston. Professor Ferrey is the author of *The Law of Independent Power*, a three-volume treatise on energy law and the environment now in its 21st edition for 2004. He is the author of *Environmental Law: Examples and Explanations*, 3d ed., 2004. He also authored “Nothing But Net,” published in 2003 at 14 *Duke Environmental Law & Policy Forum* 1, among more than 70 published articles. Professor Ferrey consults with the United Nations and World Bank on international energy issues.

1. Electricity is an energy carrier, rather than an energy source. Energy carriers must be made. The process of making them consumes other energy sources. It is always an efficiency question as to whether it is worth transforming raw fossil fuels or renewable energy to an energy carrier such as electricity or hydrogen. There are losses in efficiency in that transformation, but a higher-grade energy carrier can be produced. The calculation must factor in transportation losses and costs as well as the ultimate form in which the energy will be used.

2. While automobiles also are a significant source of air emissions, their use is much less centralized and controllable than that of electric power.

century. In addressing energy in our society, I will focus particularly on electric power, the environment, and the spatial, integrative, and dispersive forces of our energy choices. I want to address the often unappreciated and invisible energy vectors that form our society.

## I. ENERGY > SOCIETY

First, to establish the context of how energy affects us and why it matters, I want to review the historic, present and future roles of energy in shaping society. Second, I will illustrate a dozen “pivot points” involving energy choices that will shape our future and that you as lawyers, policy makers, and citizens will navigate. There are many of these issues, and to avoid duplication with the presenters who have preceded me, I focus here on how we generate and distribute electricity and the strains on our centralized system. So there are a number of important issues that I do not have space to cover here. Energy is the center stage upon which environmental law, certainly in terms of global warming and many other environmental issues, will be played.

### A. *The Age of High Energy*

Where have we come from? Exploitation of energy, as we typically think about it in commercial quantities, is *very* new. The last 250 years have been the Age of Energy. Per capita energy consumption effectively increased worldwide by about twenty-fold between 1850 and 2000.<sup>3</sup> The conversion of energy sources also increased dramatically during this period.<sup>4</sup>

Let's fix energy in its historical context. Only in the final one-tenth of one percent of human history have humans harnessed energy (in even its most basic form of using animal power) to technically advance civilization. And for electricity, its production appears only in the last two thousandths of one percent of human history. Put another way, if human history were stretched along a mile, energy capture would only occur in the final foot of this mile. In the final two inches

---

3. VACLAV SMIL, ENERGIES: AN ILLUSTRATED GUIDE TO THE BIOSPHERE AND CIVILIZATION 133 (1999).

4. Oil is the most used energy source in the world today. The U.S. Department of Energy expects world energy demand to grow by 58% between 2003 and 2025. The demand for natural gas is expected to grow while nuclear power will tend to decline through 2025 until it represents 19% of world energy requirements. By 2005, natural gas is expected to eclipse coal as the second most dominant fuel source in the world. See U.S. Dept. of Energy, *Petroleum Industry Analysis Brief* at <http://www.eia.doe.gov/emeu/mecs/iab/petroleum/index.html> (last visited May 29, 2005).

of these 5280 feet, prime movers were invented to exploit the chemical energy in fossil fuels to produce steam for industrial, heating and transportation tasks, thereby displacing the medieval windmill and creating the industrial age. Only in the final one inch, oil and electricity are harnessed. The energy that seems a staple of our existence is really quite new.

### B. *The Role of Energy Technologies*

First, human invention creates technologies that in some instances *substitute* for prior ways of performing work or tasks. Second, in other instances, new technologies provide a *complementary* good or service that combines or is deployed with other technologies to create a new process, to perform work, or to create the built environment. Third, in yet other instances, innovations create a technology that moves society in a wholly *new dimension* that changes human interaction. Each of these three types of technological impacts and forces creates competitive advantages, accelerates change, and can be socially and spatially revolutionary.

By way of example, even with the invention in the last 250 years of coal- and oil-powered rail, plane and automobile transportation, which each add speed and power, these were *substitutes* for animal-drawn or boat transportation. The great leap forward of use of fossil fuel combustion in tractor engines and agricultural machinery, although of great impact, was still a *substitute* for other animal-powered means of performing the same tasks. While these modern technologies accelerated change over two centuries, I would categorize these as more efficient substitutes for terrestrial transportation and agricultural methods that already existed—the first type of impact mentioned above. By contrast, jet rocket transportation (complemented by electric power systems) allowed a *new-dimension* technology of exploration of space, previously physically inaccessible—the third type of change and impact.

### C. *Fossil Fuels and Society*

Turning shafts, connected by gears, produces mechanical power or electricity. Burning denser fossil fuels—coal, oil, natural gas—as well as many early renewable water and wind applications, were employed to produce (rotating) shaft power for mechanical and agricultural applications. These were *substitutes* for animal-powered technologies, but also key *complementary* technologies making possible the fabrication of copper, bronze and iron, which iron and steel are

the materials for engines, automobiles, and electric power production facilities, advanced tool making and weaponry.

In historical context, the steam engine was the first new prime mover of power for practical application since the early medieval windmills.<sup>5</sup> Steam-powered railroads dispersed population along a horizontal spatial axis. Railroad development was fostered by U.S. federal subsidy and land grants to the railroads, so that they reaped the economic development benefit around their rail axes.<sup>6</sup>

Clearly, all technologies do not make equal change and impact. Fossil fuels facilitated spatial decentralization of society along a horizontal axis by dispersing population from production. Fossil energy technology drives a vast spatial dispersion of society, as a concentrated mobile energy source (coal) could be harnessed at locations not tied to flowing watercourses, as well as creating steam-powering transportation modes. The internal combustion engine powered by refined oil, implemented at personal scale via autos and trucks, further horizontally dispersing the spatial patterns of the United States into suburban sprawl across the North American continent.

The impact of the automobile on the spatial structure of the U.S. settlements has been as great as its captivity of the life aspirations of Western humankind. . . . The car came to mean autonomy, potency, and freedom. We built our suburbs and abandoned our cities for it; we ripped up our streetcar trackage for its boulevards; we invested our riches in an interstate highway net to permit a coast-to-coast drive in forty hours; and we awake in the 1980s to the realization that we now live in a spatial pattern that only the automobile can sustain.<sup>7</sup>

---

5. SMIL, *supra* note 3, at 143 – 144. (noting that Thomas Newcomen invented a powerful steam engine in 1712 whose efficiency was increased by John Smeaton and was yet again improved by James Watt by adding a separate condenser in 1769, insulating the cylinder by a steam jacket and maintaining a vacuum in the steam condenser with an air pump. Watt's centrifugal governor maintained constant speed with varying engine loads. Five hundred reciprocal and rotary steam engines were constructed by the year 1800 on Watt's invention.)

6. Sheldon L. Greene, *Promised Land: A Contemporary Critique of Distribution of Public Land by the United States*, 5 *ECOLOGY L.Q.* 707, 714 (1976) (noting that "the development of the railroads paralleled the settlement of new lands. Initially, the federal governments land subsidy to railroads was simply the grant of a right of way. . . . To finance the construction of the road, Congress initially granted five alternate sections of land per mile of railway to be located within ten miles of either side of the road bed."). *See also id.* at 720. (finding that "[t]he railroads were no more than a vehicle to convey the land from the public domain to settlers.").

7. "The automobile, in contrast to the streetcar or the subway, emphasized social distinctions and permitted many gradations of comfort and style. It appealed strongly to the middle class that patronized the street railways, whose routes had helped to create the suburbs where they lived. By 1920, however, the automobile had created a class gap between those who drove

The suburbs exist only because of the automobile, and the automobile existed only because of cheap oil.<sup>8</sup> Today, there are more than one-half billion automobiles, or one car for every eleven people in the world. Automobiles have been claiming an increasing share of global primary energy consumption. Forty percent of all liquid fuel consumed in North America is for automobiles.<sup>9</sup>

Modern agriculture in the United States and other industrialized countries has become dependent upon oil. Note the links—direct and indirect—between fossil fuel use and environmental degradation. Feed-lot agricultural practices for the raising of cattle and other animals constitute an energy-intensive, environmentally polluting activity. Feed-lot cattle are fed low-cost corn to fatten the animal over a period of slightly more than a year to the point of slaughter, where range-fed and grazed animals might take up to five years to achieve a similar size and be ready for slaughter. The use of corn to fatten cows in feed-lot agriculture consumes more chemical herbicide and fertilizer than any other crop. The nitrogen from that crop fertilizer runs off into water bodies and groundwater in farming communities, and then into major rivers traversing multiple states.

The fertilizer necessary to grow that corn is derived from oil fields (principally in the Persian Gulf and other foreign nations). Thus, modern animal agriculture is driven by, and dependent on, fossil fuels. A cow that eats 25 pounds of corn per day so as to reach a weight of 1,250 pounds at the point of slaughter has indirectly “consumed” approximately 284 gallons of oil in the form of the petrochemical fertilizers necessary to grow that corn. Thus, our modern agricultural system is dependent upon fossil fuels across the food cycle. In essence, this fossil fuel agricultural “machine” has replaced a natural solar-powered renewable system where animals previously grazed on an open range, eating grasses that were naturally produced by photosynthesis driven by solar power and the natural nitrogen and phosphorus cycles.

Fossil fuels thus foster the organization of society in more dense and concentrated, as well as dispersed, spatial form.

---

and those who rode." DAVID NYE, *ELECTRIFYING AMERICA: SOCIAL MEANINGS OF A NEW TECHNOLOGY 1880 – 1940*, at 133 (1990).

8. "Metropolitan boundaries have been dramatically extended by the automobile, a creature dependent on cheap oil." VANTIL, *LIVING WITH ENERGY SHORTFALL: A FUTURE FOR AMERICAN TOWNS AND CITIES* 93 (1982).

9. SMIL, *supra* note 3, at 184. Jet fuel consumes less than six percent of the world's refined petroleum products. *Id.* at 187.

#### D. *Electric Power and Society*

Electricity is a unique energy form. Electricity is a substitute, complementary and unique-dimension technology:

- Electricity is a substitute for other heating, lighting, and transportation technologies.
- Electricity is a complementary technology for computing, space exploration technology, and military applications, among many others.
- Electric power is a technology that adds unique dimension by exploiting the electro-magnetic spectrum.

Modern manufacturing was revolutionized by the invention of the electric motor where each production process could be mechanically isolated by a separate motor. Today all modern fast trains are driven by electric motors.<sup>10</sup>

Electric technology is a necessity for the vertical high-rise dimension of cities. Without elevators and air conditioning, which are often taken for granted, there could be no high-rise office design, because it would be impossible to efficiently get furniture, fixtures, and people to significant heights within buildings and it would be impossible to cool buildings to comfortable levels.<sup>11</sup> Electricity has no substitutes for computer technology and the Internet. The rapid exchange of information and computerization are directly dependent on electricity; Reliable electric supply and quality is a prerequisite.

Modern energy technologies now shape and dominate culture.<sup>12</sup> In several dimensions, electricity is unique. First, while oil and coal-powered transportation technologies allowed society to disperse horizontally, electricity as a complementary power adds a high-rise vertical spatial dimension. Second, the impact of electric power is distinct from other major technological innovations in terms of magnitude. Where harnessing of domesticated animals or deployment of fossil fuels provided a ten-fold or sometimes greater increase in work, power, or speed of performing tasks, electricity accelerated the amount and speed of work not ten-fold or one-hundred-fold, but to the asymptotic physical maximum near the speed of light.

---

10. SMIL, *supra* note 3, at 178. Modern rapid trains run on AC current at 15 to 25 kV.

11. Even in many cold climates, office buildings with fixed, immovable windows are air conditioned during the winter months to remove all of the heat produced by persons, lighting, and electric equipment.

12. Friedrich Rapp, *The Material and Cultural Aspects of Technology*, 4 PHILOSOPHY AND TECHNOLOGY 48 (Spring 1999).

Third, electricity fosters connectivity. Electricity “restacks” human interaction and communication through the Internet, television, radio, telephone, and modern communications and information transfer. Electrically-powered technologies provide a virtual (vertical) proximity that counteracts the (horizontal) spatial dispersion created by industrial-age fossil fuel technologies. Electricity re-orders the physical spatial orientation of a horizontally dispersed society.

Fourth, electric energy transfer occurs instantaneously. Other conventional energy forms—wood and fossil fuels—are distributed by direct physical labor (or at up to 30 mph in a natural gas pipeline). Electricity moves at  $\approx 186,000$  miles per second and can be distributed instantaneously throughout a service area.

Fifth, electricity and the electromagnetic spectrum are unique carriers and transmitters. Electricity can itself be the medium to transmit continuously millions of units or bits per second of information as audio, text, or other information. In terms of speed and volume, electricity is a unique carrier of human intellectual content, and thus uniquely dimensional as a technology. Electricity is the post-industrial technology that offers substitutes for certain other industrial technologies, yet is unique in providing the technological platform for the post-industrial service economy and modern communications, computing, and advanced scientific research technologies. Ideas diffuse instantly on the Internet, and the balance of power has changed in favor of those who control technology and the energy sources that power technology.<sup>13</sup>

Electric energy policy matters now more than ever because of the recent explosion in demand for electricity. Electricity was not harnessed commercially until the late nineteenth century: In 1900, less than 1% of all fossil fuels were converted to electricity; by 1945 this share had risen to 10%; by 1990 the share had risen to 25%. This correlates to a quintupling of global *per capita* electricity use between 1950 and 1995. In 1950, per capita global electricity consumption was 400 kilowatt hours (“kWh”),<sup>14</sup> which had increased to 2300 kWh in 1995. The rate of growth in electricity use is unlikely to slow down anytime soon; electricity is the fastest growing heating source in the United States. For example, electricity was the primary home heating

---

13. JARED DIAMOND, *GUNS, GERMS AND STEEL: THE FATES OF HUMAN SOCIETIES* 417 (1997).

14. The kilowatt hour is a standard unit for measuring electricity consumption.

“fuel” in 32 million U.S. households in 2000, a 35% increase since just 1990.<sup>15</sup>

## II. A DOZEN “PIVOT POINTS” FORMING THE ENERGY FUTURE

### A. *Fossil Flavor of the Decade*

The United States has a penchant for consuming more fossil-fuel energy than it produces. During the energy “embargos” of 1974 and 1979, the United States learned first-hand the international and economic repercussions of importing half of its oil. Today, the United States imports even a higher percentage of its oil from abroad. What has changed is that less of it is from OPEC or hostile nations.

However, a “pivoting” supply change now occurring is the significant increase in the use of natural gas for electric generation. For example, in 1999, the New England electric power mix was 16% gas; By the end of 2005, it will be more than 40% natural gas.<sup>16</sup> From 1999 to 2004, North America added 200,000 megawatts (“MW”)<sup>17</sup> of new electric capacity, 94% of which was fueled by natural gas. That makes just the new gas-fueled electricity capacity constructed in this five-year period about twice as large as all U.S. nuclear power plants.<sup>18</sup> Between 2003 and 2008, the amount of natural gas burned in power plants nationally is expected to increase by 30%.<sup>19</sup> As of 2003, thirty-five percent of California generation was fueled by natural gas, again making it dependent to a significant extent upon the most volatile and highest priced fossil generation fuel. The California Energy Commission called for accelerating renewable portfolio standards to require 20% of all retail sales come from renewable power by the year 2017.<sup>20</sup> This increase is driven significantly by the preference for natural gas because of its lower NO<sub>x</sub>, particulate and SO<sub>2</sub> emissions when combusted to produce electric power. In addition, natural gas is easily

---

15. Natural gas supplied 54 million households, a 16% increase since 1990. Six-point-eight million households relied on propane as the primary home heating fuel, while 9.4 million households relied on fuel oil, an 11% decline since 1990.

16. LEVITAN & ASSOCIATES, TECHNICAL ASSESSMENT OF DELIVERY CAPABILITY Ch. 2 (2001) (prepared for New England ISO).

17. The megawatt is a standard unit for measuring electrical generation capacity.

18. *Does U.S. Face Rerun of 1970's in Gas?*, ELECTRICITY DAILY, July 15, 2004, at 2.

19. *Gas Demand Crunch Looms Without New Plants, Reagan Told*, THE BOSTON GLOBE, Sept. 12, 2004, at C1, C5.

20. *Calif. Energy Commission Sees Supply as Tenuous in Latest Policy Report*, ELECTRIC UTILITY WEEK, Sept. 22, 2003, at 27. There is a goal of equipping 50% of all new homes with solar photovoltaic electric panels by the year 2005.

transported in the intrastate pipeline system. The same over-weighted reliance on oil in the 1970s is being repeated now with natural gas, albeit for environmentally motivated reasons.

The United States now has exceeded its and even North America's ability to supply sufficient natural gas for the U.S. market. Therefore, natural gas will now be increasingly imported in the form of liquefied natural gas ("LNG"). As of 2000, there were only 3 operating LNG facilities in the United States. There are several dozen applications pending for siting of new LNG terminals. All face significant local siting opposition.

A significant amount of exportable natural gas is located in politically unstable, diplomatically unfriendly, or openly hostile countries. This increasing dependence for natural gas imports for electric power plants will influence geopolitics, U.S. foreign relations, and diplomacy. It will put new pressures on the U.S. military to defend key natural gas sources and transportation links. By importing significant quantities of both LNG and oil, in the decades immediately ahead, energy will become even more intertwined with an often confused United States foreign policy. All of this will be driven, somewhat below the radar screen of common perception, by U.S. electric power consumption and choices. The challenge for the future is to "pivot" to reduce international vulnerability.

#### *B. Waning of the Fossil Base and Shift to Renewable Energy*

Our supply is limited. Our appetite is not. In 1997, all nations on earth consumed 26.4 billion barrels of oil, 81.7 trillion cubic feet of natural gas, and 5.2 billion tons of coal—all of which are millennially decayed organic matter previously brought to life by the sun. It was estimated that U.S. domestic gas output in 2004 will fall slightly below the prior year and imports of natural gas from Canada to the U.S. will fall 3% in 2004 and almost that much again in 2005. At the same time, natural gas demand is expected to increase 0.4% in 2004 and 0.7% in 2005, according to the U.S. Department of Energy, EIA.

New renewable generation technologies allow the ability to use renewable sources or chemical conversions of energy potential (such as fuel cells). This can represent a paradigm shift from traditional burning as the mechanism to release energy potential to chemical energy conversion: "Fire turns out to be a clumsy and messy way of ma-

nipulating the world.”<sup>21</sup> Valuing the chemical energy in various fuels, rather than the heat-based potential, opens the door to a new way of seeing an alternative path *to* the energy future.

While many nations—particularly developing nations—have no significant reserves of oil, coal or natural gas, every nation has solar energy in some form—sunlight, wind, biomass, geothermal, ocean wave power, etc. This makes the commercial and national interests involved in fossil fuel extremely concentrated, while solar energy interests and flows are much more decentralized and diverse.

We must transition to renewable energy. It is reassuring that renewable technologies are available. It is frustrating that this transition is guided by no plan and is not well along. It is a significant alteration in technologies for power generation. How and when we facilitate this collective “pivot” will either decentralize or centralize the shape and vectors of power of our world. It is a key and imminent choice.

### C. *The Imperative of Greater Efficiency*

We will be forced to become much more efficient to be globally competitive and to offset higher prices for imported fossil fuels. It is also important to realize greater self-sufficiency. This country has never faced a sustained or severe disruption of fossil fuels. This efficiency imperative will favor a significant shift to cogeneration over time.

Both conventional electric generation technologies and industrial process heat applications are inefficient. Conventional electric generating technologies typically exhaust as much as two-thirds of the energy (as heat) produced to power electric generators.<sup>22</sup> Combustion of fossil fuels to produce that heat results in temperatures of more than 3000 degrees Fahrenheit, much of which is wasted.<sup>23</sup> However, industry uses process steam most often in applications below 400 degrees Fahrenheit—so this waste heat is of sufficient thermal content to be usable. With the technology of combustion near its practical limit, the next major leap in efficiency must come from recovering and reusing waste heat in industry and for space heating.

---

21. STEPHEN L. GILLET, *NANOTECHNOLOGY: CLEAN ENERGY AND RESOURCES FOR THE FUTURE* 9 (2002).

22. See generally *ENERGY FUTURE* (R. Stobaugh & D. Yergin eds. 1979); AMORY LOVINS, *SOFT ENERGY PATH* (1977); B. COMMONER, *THE POVERTY OF POWER* (1976).

23. Cogeneration Technologies, *Hydrogen Fuel*, available at <http://www.cogeneration.net/HydrogenFuel.htm> (last modified 2003) (partner with U.S. E.P.A. Combined Health and Power Partnership).

Part of the solution could be greater use of cogeneration. Research sponsored by a federal energy laboratory concludes that distributed cogeneration of combined heat and power would increase energy efficiency of the U.S. economy.<sup>24</sup> Cogenerators that recover and use waste heat and sequentially produce electricity have the capability to achieve efficiencies from 50 to 90 percent, much better than the typical 30-plus percent efficiency of the existing central station utility fossil steam electric generation system. Thus, cogeneration facilities operate at overall thermal efficiencies as great as 250-300 percent higher than conventional electric generating technologies.<sup>25</sup> The very best cogeneration technologies are more than twice as efficient as new coal-fired power plants.<sup>26</sup>

Thermodynamically, the advantage of cogeneration technologies compared to conventional electric generating technologies is that they can raise efficiency under the first law of thermodynamics.<sup>27</sup> This first-law efficiency for electricity production increases from about 33 percent to as high as 90 percent or more with cogeneration.<sup>28</sup> Cogeneration technologies can raise efficiencies under the second law of thermodynamics<sup>29</sup> from 35 percent to as high as 49 percent.<sup>30</sup> This results

---

24. A. Jalalzadeh-Azar, *Quantifying Potential of Integrated Energy Systems with a Varying Level of Nationwide Deployment*, NATIONAL RENEWABLE ENERGY LABORATORY, NREL/TP-550-32754 1 (Nov. 2002). This research factors in that a possible recoverable 80% of waste energy from prime movers can be achieved, electric space heating represents about 7% of total national energy consumption, and that a typical direct fossil-fuel heating device has an efficiency of 80%. *Id.* at 3. It also factors in that space air conditioning comprises 36% of total building energy consumption (25% for heating and 11% for cooling) and water heating constitutes an additional 12% of total building energy demand. This percentage could be met by heat recapture of distributed energy systems. *Id.* at 4. Up to 100% of cooling commonly is provided by electrical equipment. It also assumes that microturbines equipped with recuperators offer efficiencies of 23 to 27% while large gas turbines have efficiencies in excess of 40% when utilizing inlet air cooling. *Id.* at 5.

25. *Id.* at 1 – 3.

26. A large, modern, coal-fired central-station power plant has a heat rate of 10,500 Btu/kWh. The most efficient cogeneration units have a heat rate of 4,500 Btu/kWh. See, Capehart & Capehart, *Efficiency in Industrial Cogeneration: The Regulatory Role*, 125 PUBLIC UTILITIES FORTNIGHTLY 17 (Mar. 15, 1990).

27. The efficiency of a heat engine, which is a device that converts chemical energy to mechanical or electric energy, is governed by the first and second laws of thermodynamics. The first law of thermodynamics simply measures the percentage of chemical energy input that is converted to useful thermal and electric energy. It reflects the efficiency of energy originally in a chemical form converted to other forms.

28. M.H. ROSS & ROBERT H. WILLIAMS, *OUR ENERGY: REGAINING CONTROL* 156 (1981).

29. The second law of thermodynamics reflects the quality of energy produced. Electric energy is of much higher quality than thermal energy. The Carnot efficiency expresses the ratio of the useful (electric and heat) output of an engine as a fraction of the total energy input. In

in efficiency savings of fuel input needed to generate a unit of usable energy output by various cogeneration technologies, when compared to conventional electricity generation technologies, of up to 31 percent.<sup>31</sup> This translates to fewer pollutant emissions. With optimum full implementation of distributed energy systems with heat recapture 40% of building primary energy consumption could be conserved if distributed energy systems were installed in lieu of conventional centralized electricity production.<sup>32</sup>

We must be more efficient to stretch our resources, remain globally competitive, and protect the planet. This “pivot” should lead us to closely consider alternatives such as cogeneration.

#### D. *Environmental Preservation with Electric Energy Alternatives*

There are environmental imperatives associated with electric energy production. The threats of global warming from the release of prodigious quantities of carbon and the other greenhouse gases are well documented.<sup>33</sup> The rate of increase of electric production occurring in the developing world, the great bulk of it from fossil fuels, is alarming. Solutions to carbon deposition must be found in the technologies used and the efficiencies achieved in electric production.

Moreover, recent data suggests that criteria pollutants from electric power plants are drifting continentally—Asian pollution is reaching the Western United States and U.S. pollution is drifting to Europe. Whether the United States adopts the Kyoto Protocol to control carbon or not, the plethora of environmental risks will become primary drivers in the choice and siting of additional energy technologies in both developed and developing countries. This will

---

essence, the Carnot efficiency predicts the maximum potential usable energy output that can be generated by different engine technologies. In practice, no engine actually achieves its Carnot efficiency because of engine friction, heat loss, heat exchanger limitations, and problems with working fluids. However, efficiency predicted under the second law of thermodynamics scales various technologies as to their relative potential efficiencies.

30. ROSS & WILLIAMS, *supra* note 28. See also R.H. Williams, *Industrial Cogeneration*, in 3 ANN. REV. OF ENERGY 313 (1978).

31. ROSS & WILLIAMS, *supra* note 28. Typically, cogenerators utilize 80 percent of the fuel of conventional stand-alone generation to produce an equivalent amount of energy output.

32. Even with only 60% of recoverable thermal energy from on-site distributed generation utilized, the research concludes that this result conserves more energy than even advanced central system energy generation. It concludes that this is synonymous with reductions in emissions to the environment. *Id.* at 7.

33. STEVEN FERREY, WINNING THE WAR AGAINST GLOBAL WARMING FROM THE GROUND UP Ch. 2 (forthcoming 2005).

result an increased deployment of renewable and efficient cogeneration technologies.

Environmental costs associated with power plants occur at each of three stages of the energy process: at the point of extraction and processing of energy sources,<sup>34</sup> direct costs associated with the use of energy sources,<sup>35</sup> and back-end residual management and disposal costs.<sup>36</sup> The primary impacts on human health from direct production of electric energy are from emissions of carbon dioxide<sup>37</sup> and the criteria pollutants, sulfur dioxide (“SO<sub>2</sub>”),<sup>38</sup> NO<sub>x</sub>,<sup>39</sup> ozone,<sup>40</sup> particulates,<sup>41</sup> and acid deposition.<sup>42</sup>

---

34. Front-end costs include the costs of drilling, mining, or otherwise extracting raw fuel sources, the processing, enrichment or concentration of these fuel sources, the manufacture of equipment to effectively utilize these fuel sources, and transportation costs for fuel and equipment.

35. These include the emission of a variety of pollutants, health impacts from these emissions, impacts on the natural environment of such emissions, and human occupational exposure or illness at the power plant work site. The primary effects on human populations are the increased risk of mortality and morbidity, including chronic illness and increased risk of chronic disease.

36. These include waste disposal costs for residual elements of fuel and the eventual costs of decommissioning energy producing facilities.

37. Carbon dioxide, which is released by burning fossil fuels and deforestation, is thought to account for about half of the greenhouse effect.

38. Particulates are solid or liquid substances in a wide range of sizes, produced primarily by stationary fuel combustion and industrial processes. While some particulates or particulate matter, as they are commonly referred to, are noncombustible material from the original waste input, some are condensed gases from material vaporized during incineration but cooled into or onto particles. Arnold W. Reitze, Jr. & Andrew N. Davis, *Regulating Municipal Solid Waste Incinerators under the Clean Air Act: History, Technology and Risks*, 21 B.C. ENVTL. AFF. L. REV. 1, 21 (1993). Particulate matter is formed from noncombustible constituents in fuel or in the combustion air, from products of incomplete combustion, or from formation of ammonium sulfates after combustion. These typically are unburned by hydrocarbons and sulfur. Environmental Protection Agency, *PM - How Particulate Matter Affects the Way We Live & Breathe*, available at <http://www.epa.gov/air/urbanair/pm/index.html> (last visited April 15, 2005) [hereinafter EPA PM].

39. NO<sub>x</sub> is formed by the conversion of chemically bound nitrogen in the fuel or from thermal fixation of atmospheric nitrogen in the combustion air. Environmental Protection Agency, *NO<sub>x</sub> - How Nitrogen Oxides Affect the Way We Live and Breathe*, available at <http://www.epa.gov/air/urbanair/nox/index.html> (last visited April 15, 2005).

40. Ozone causes damage to human health, agriculture, and plant life. *Id.*

41. Particulates include solid particles and liquid matter which range in size from one micron to more than 100 microns in diameter. They are responsible for major health impairment, impairment of visibility by causing haze, and the creation of sulfate from SO<sub>2</sub> emissions. EPA PM, *supra* note 38.

42. Acid deposition causes damage to forests, wildlife, water quality, and aquatic species. Environmental Protection Agency, *Acid Rain*, available at <http://www.epa.gov/airmarkets/acidrain/index.html> (last visited April 15, 2005).

But hope is on the way, in the form of renewable technologies, cogeneration and distributed production. Renewable technologies are cleaner than fossil fuel-fired technologies, and cogeneration may have similar benefits for the environment. And in most applications, distributed electric production tends to decrease air emissions.<sup>43</sup>

Cogeneration facilities should cause fewer environmental impacts than equivalent megawatts of conventional power production. Various cogeneration technologies can reduce the levels of SO<sub>2</sub>,<sup>44</sup> particulate matter, CO<sub>2</sub> and NO<sub>x</sub><sup>45</sup> per unit of useful energy output, although certain technology configurations can also increase the discharge of these critical emissions.<sup>46</sup> This substitution of an integrated cogeneration technology, in lieu of conventional separate electricity and thermal energy production technologies, should save 15-25 percent of the energy input otherwise consumed by, and the emissions from, separate conventional energy production configurations.<sup>47</sup>

Where independent distributed generation is effectively employed, one author has calculated that the value to the system and the customer in terms of environmental savings, reliability, engineering cost savings, electric and thermal energy value, and system deferral value can range between \$300 and \$1,000/kW per year or higher.<sup>48</sup> However, the customer does not internalize or realize all the benefits; Many of these benefits accrue most directly to the host utility. We require new legal and regulatory mechanisms to re-allocate the value of these benefits as incentives to those who provide cogeneration and renewable resources for the system. This will require a regulatory

---

43. AMORY LOVINS, ET AL., SMALL IS PROFITABLE: THE HIDDEN ECONOMIC BENEFITS OF MAKING ELECTRICAL RESOURCES THE RIGHT SIZE 303 (2002).

44. A diesel cogeneration system using 0.2 percent sulfur No. 2 oil could save about 0.1 lb. of SO<sub>2</sub> for every 100 kWh of electricity generated by the facility. U.S. Congress Office of Technology Assessment ("OTA"), *Industrial and Commercial Cogeneration*, App. B (1983).

45. A gas turbine cogeneration system can reduce NO<sub>x</sub> emissions by about 0.3 lb. for every 100 kWh of electricity generated by the facility. *Id.*

46. A shift in electricity generation from utility central-station conventional technologies to either gas or diesel turbine cogeneration systems will actually increase NO<sub>x</sub> emissions, and the latter technology will also increase carbon monoxide ("CO") and particulate emissions. *Id.*

47. A 15% reduction in fuel use should accompany a change from separate steam electric generator and separate low-pressure steam boiler to a steam electric cogeneration system. *Id.* at 223.

48. JOEL N. SWISHER, ROCKY MOUNTAIN INSTITUTE, CLEANER ENERGY, GREENER PROFITS: FUEL SALES AS COST EFFECTIVE DISTRIBUTED ENERGY RESOURCES 29, (2002) (citing LOVINS ET AL., *supra* note 43), available at [http://www.rmi.org/images/other/Energy/U02-02\\_CleanerGreener.pdf](http://www.rmi.org/images/other/Energy/U02-02_CleanerGreener.pdf) (last visited July 18, 2005).

“pivot” and redistribution of supply and cost responsibility and rewards.

### E. *Terror and System Disruption*

Centralized infrastructure is vulnerable. Whether by supply shortage, transmission system fault or terrorist attack, our current centralized electric supply and distribution system is remarkably fragile and vulnerable. While the embargos of 1974 and 1979 demonstrated that society would be radically altered by a sudden perceived scarcity of oil fuel, it also is significantly altered by a shortage or failure of electricity. If utility transmission towers or pipelines are physically destroyed or disrupted, it can take weeks to repair them. Because electricity cannot be easily stored or rerouted, supply must instantaneously match demand on a second-by-second real-time basis. Particularly in the aftermath of the attacks on the World Trade Center, the security of the centralized electric supply and distribution system in the U.S. has been subject to substantial scrutiny. It is quite likely that disruption of the electric generation system can be a target of terrorism in our future.

A U.S. commission concluded that a single nuclear weapon exploded at high altitude instantly could degrade at least 70% of the U.S. electric service.<sup>49</sup> Such an explosion would create a magnetic field that would radiate back down to earth creating currents that would cascade through major U.S. electrical infrastructure, rendering it inoperable. The immediate flux of gamma rays would create electrons trapped in the Earth’s magnetic field giving rise to an oscillating electric current, creating an electromagnetic pulse which could wipe out the electric power infrastructure, telecommunications and other dependent infrastructures. The commission concluded that such an attack “has the potential to hold our society seriously at risk and might result in defeat of our military forces.”<sup>50</sup> The commission found evidence that enemies of the United States have considered such attacks in the past and concluded that such attacks by terrorists or states might be difficult to deter.<sup>51</sup> Rather than destroying a specific city or site, destruction of the sophisticated electric and electromag-

---

49. JACK SPENCER, THE ELECTROMAGNETIC PULSE COMMISSION WARNS OF AN OLD THREAT WITH A NEW FACE (2004) available at <http://www.heritage.org/Research/NationalSecurity/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=67303> (last visited July 18, 2005).

50. *Id.* at 1.

51. *Id.*

netic infrastructure of a nation might pose even more catastrophic results.

Security is not only physical, but virtual. In 2004, most utility infrastructure and control systems remain vulnerable to cyber attacks that can endanger public health and safety, according to the U.S. General Accounting Office,<sup>52</sup> and in many cases to physical attacks. In July 2003, *The Washington Post* reported that a George Mason University student had mapped every business and industrial sector in the American economy, layering on top the fiber-optic network that connects them, including connections used by power companies.<sup>53</sup> This project started as a student dissertation and utilized non-classified information from the Internet.<sup>54</sup>

We are not used to significant outages. Between 1965 and 1995, there were two major U.S. electricity service outages over those thirty years,<sup>55</sup> while there were four major U.S. outages between 1996 and 2003.<sup>56</sup> The final of these four more recent outages occurred on Au-

---

52. GAO: *SCADA Systems Vulnerable to Terrorists*, 22 ELECTRICITY DAILY 1 (2004).

53. Laura Blumenfield, *Dissertation Could be Security Threat; Student's Maps Illustrate Concerns About Public Information*, WASHINGTON POST, Jul. 8, 2003, at A01.

54. Jennifer Alvey, *Cyber Security: A 'Virtual' Reality*, PUBLIC UTILITIES FORTNIGHTLY, Sept. 15, 2003, at 50.

55. There was the famous blackout of November 9, 1965, that affected all of New York, Connecticut, Massachusetts, Rhode Island and small segments of northern Pennsylvania and northeastern New Jersey, as well as substantial areas of Ontario, Canada. It impacted 30 million customers consuming 20,000 MW and lasted up to thirteen hours. After a protective relay opened on one of the lines taking power north from a plant in Ontario, within 2.5 seconds a cascading blackout occurred. After this event, NERC was formed. On July 13, 1977, 9,000 people consuming 6,000 MW in New York City were blacked out for twenty-six hours when the entire ConEdison system collapsed as a result of two 345 kV lines being struck by lightning and tripping out. The New York City system separated from surrounding systems and collapsed when generation inside New York City was not adequate to serve city load.

56. On July 2, 1996, there was an outage that affected Arizona, California, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, Oregon, South Dakota, Texas, Utah, Washington and Wyoming, as well as parts of western Canada and Baja, California involving two million customers consuming about 12,000 MW for up to a few hours. A line shortage in a 345 kV line caused the inability to carry power away from a generating plant in Idaho which caused a decline in frequency in the Western Interconnection resulting in scattered customer outages. On August 10, 1986, an outage hit Arizona, California, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, Oregon, South Dakota, Texas and Utah affecting 7.5 million customers consuming 28 MW for up to nine hours. This was triggered by a combination of random transmission line outages in resulting system oscillations when a 500 kV line shorted due to touching trees and led to overloads and cascading outages throughout the Western Interconnection and certain transmission mismanagement. On June 25, 1998, Minnesota, Montana, North Dakota, South Dakota and Wisconsin, as well as parts of Canada, involving 152,000 customers with 950 MW of demand, lost power for up to eighteen hours due to a lightning storm that struck a 345 kV line and de-energized it and overloaded lower voltage lines which were then de-energized causing system protection to take lines out of service throughout the MAPP region.

gust 14, 2003, a typical summer day, when transmission capacity problems in Ohio caused significant parts of the Midwest, New York, and Mid-Atlantic region, involving 50 million customers, to lose power for up to a day. This constituted the largest blackout impact in modern North American history.<sup>57</sup> More than two hundred power plants, including twenty-two of the nation's nuclear plants, were tripped off-line. The Brattle Group estimated that the August 2003 blackout cost businesses, alone, \$6 billion, with \$75 million compensated by business insurance, given that less than 10% of U.S. businesses purchased blackout insurance.<sup>58</sup>

Outages and other significant power fluctuations cost the United States nearly \$30 billion in 1999, according to the U.S. Department of Energy.<sup>59</sup> Collectively, the rolling California blackouts in 2001 cost Silicon Valley businesses an estimated \$75 million a day; the rolling brownout in the first two weeks of January 2001 cost the state economy \$2.3 billion due to production cutbacks and lost wages.<sup>60</sup> The 20 hours of outages are estimated to have reduced gross state output by \$21.8 billion,<sup>61</sup> and reduced household income by \$4.6 billion more.<sup>62</sup>

We must adapt to prevent the very real threat of terrorist disruption of the power system, a significant "pivot point" for the future.

---

57. In this blackout, the overflow of power spread so quickly that protective equipment in various parts of the Midwest and New York were not able to isolate outages before they spread to neighboring areas. Other parts of the PJM grid were able to isolate power flows as the power started to deviate below 60 MHz.

58. *Blackout Adds to Long List of Utilities Woes*, THE BALTIMORE SUN, Aug. 24, 2003. The Brattle Group estimated that the August 2003 blackout cost businesses, alone, \$6 billion, with \$75 million compensated by business insurance, given that less than 10% of U.S. businesses purchased blackout insurance. *Blackout to Cost Insurers \$75 Million*, CHICAGO TRIBUNE, Oct. 14, 2003, at C3.

59. *Clean, Efficient Energy Technology Offers Cheapest, Most Reliable Solution to Utility Reliability Problem*, available at [http://www.ems.org/lighten\\_the\\_load/docs/nycheapestsolution.html](http://www.ems.org/lighten_the_load/docs/nycheapestsolution.html) (last visited July 18, 2005). Each dollar of output for one industry represents the purchase of goods and services by other industries.

60. Ann Deering, *The Expanding Energy Crisis: United States*, RISK MANAGEMENT, May 1, 2001.

61. AUS Consultants, *Impact of a Continuing Electricity Crisis on the California Economy*, May 3, 2001, at ii.

62. California Alliance for Energy & Economic Stability, *Study on the California Blackout*, May 2001, available at [www.caltox.org/member/digest/june2001/jun01-03.htm](http://www.caltox.org/member/digest/june2001/jun01-03.htm) (last visited July 18, 2005).

### F. *Elevating Transmission and Delivery*

In the future, electric transmission will ascend from the shadows of generation issues. It has always been the unseen small child of the system. During the last thirty years, power demand in North America has jumped thirty percent while transmission capacity to move power has increased only half that much. The blackout of 50 million consumers in August 2003 illustrated that the interstate transmission system is at least as important to the nation as the interstate highway system or the interstate natural gas pipeline system.

There are issues of managing, planning, coordinating and communicating in real time to make an integrated United States transmission system recognize and isolate system faults. Dispatch and control systems must have the legal and practical ability to control a product moving at the speed of light. As the blackout of 2003 illustrated, there may be a matter of just a few seconds that electronic and manual grid operation has to respond to a major power destabilization in order to protect the quality of service.

Grid regulation does not stop at state lines. In the blackout of 2003, the relatively weak Midwest ISO did not have over-arching authority to order operational changes or responses within the region; Instead they had to call each generating plant owner and each utility to suggest operational changes.<sup>63</sup> Human error, loss of a line, and computer failures made contingency analysis of no value, set off a cascade of interruptions on high voltage lines and tripping off 263 power plants.<sup>64</sup>

Why are we still so disintegrated? There has been significant resistance in low-cost generation states in the Midwest, Northwest, and South, which are still mostly conventionally regulated, to allowing transmission infrastructure upgrades that would facilitate the export of their low-cost power to higher-cost markets and states.<sup>65</sup> If this oc-

---

63. U.S.-CANADA POWER SYSTEM OUTAGE TASK FORCE, FINAL REPORT ON THE AUGUST 14, 2003 BLACKOUT IN THE UNITED STATES AND CANADA: CAUSES AND RECOMMENDATIONS 67 (2004).

64. Kennedy Maize, *Analysis: The Hows and Ways of the Big Blackout*, ELECTRICITY DAILY, Nov. 20, 2003, at 1.

65. A number of states have been extremely parochial in their exercise of transmission siting authority and exercise of eminent domain power to site necessary transmission facilities. Such parochial views may retard sufficient investment by investors to make capital investments in fixed transmission assets. In several states, incumbent players have used siting laws to preclude new market entrants. Ashley Brown & Damon Daniels, *Vision Without Site: Site Without Vision*, ELECTRICITY DAILY, Oct. 2003. The authors cite experience in Florida and Connecticut as examples of parochial exercise of transmission authority to attempt to block integrated re-

curred, it could increase the ultimate cost of power to low-cost power states; Regulators in those states have used their state authority to frustrate grid upgrades. It is out of such areas that the blackout of 2003 appears to have emanated. If we are going to overcome these structural vulnerabilities, we must plan power regionally. This involves a significant legal “pivot” in the way we regulate and structure the energy future.

### G. *Moving Gas or Electricity?*

There is a parallel natural gas transmission network crossing most of the United States that in some cases traverses the same rights-of-way as the electric transmission grid. With the development of distributed generation and/or electric storage, on-site generation supplants the requirement for additional use of electric transmission capacity. Such movement of natural gas-to-fuel distributed generation competes with the movement of produced electric power along the grid: One can either centrally produce electricity and move it to the consumer or move natural gas (or other fuels) to or near the consumer to produce electricity (not dependent on long-distance centralized transmission services).

On average, the cost to transmit electricity is approximately double the cost to ship the amount of natural gas required to make the equivalent amount of electricity.<sup>66</sup> This argues for siting electric generation close to load centers rather than constructing additional transmission infrastructure to move electricity long distances from centralized generators. As mentioned early, the value to the system and the customer in terms of environmental savings, reliability, engineering cost savings, electric and thermal energy value, and system deferral value can range between \$300-\$1,000/kw per year or higher.<sup>67</sup> One way to view distributed generation is that if natural gas-fired cogeneration increasingly replace centrally dispatched electricity, energy will be moved more in its primary form by natural gas pipelines

---

gional grids and more robust facilities to move and share power across state and regional lines. The authors suggest either regional compacts to preempt individual state authority or federal preempted siting authority. *Id.* at 27 – 29.

66. Rodney Frame & Michael Quinn, *Large ITOs and Traditional Transmission Pricing Don't Mix*, ELECTRICITY JOURNAL, Jan./Feb. 2002, at 50.

67. SWISHER, *supra* note 48, at 29. Less transmission capability would be required if there is development of dispersed electric and total energy systems located close to load center. Not only will additional transmission capacity not be required in certain areas, but existing capacity on existing transmission grids will be unburdened.

to distributed generators and less in its derived form as electricity that then undergoes transmission and distribution losses.

Furthermore, because renewable energy sources are not under the control of any nation or cartel, but are democratically distributed across the earth, they are not subject to embargo or manipulation.<sup>68</sup> Because decentralized renewable energy sources are developed in relatively small modules, this promotes reliability and resiliency of the system.<sup>69</sup> Because decentralized energy resources are built close to their points of use, they are not as dependent on long transmission and distribution networks and are less vulnerable to supply disruption from an overloaded system line, storm, or intentional disruption.<sup>70</sup> A move to greater reliance on either cogeneration or distributed dispersed renewable energy sources will decentralize the sources of power. This “pivots” institutional power relationships.

#### H. *Greater Reliability: Dispersion of Independent Electric Generation*

Thomas Edison had an original vision of a decentralized, direct current-based electric power industry composed of small individual operating businesses. Initially, the majority of electric power generation was distributed on the site of the primary consumer of that power. While this came into being from approximately the late 1880s to early in the twentieth century, this model did not prevail.<sup>71</sup>

Technology trends over the late industrial age favored centralization of utility supply. In the early years of electric power, generating stations were less reliable than the transmission and distribution (T&D) grid. Therefore, it made sense to connect many generation facilities to a common T&D network. This also made it possible to con-

---

68. "Being inexhaustible and relying only on domestic energy flows, renewable sources can never place this nation at the mercy of other countries which control dwindling and scarce fuel resources." LOVINS, *supra* note 22, at 288 – 89.

69. "A resilient energy supply system should consist of numerous, relatively small modules with a low individual cost of failure. The philosophy of resilience, on the other hand, accepts the inevitability of failure and seeks to limit the damage that failure can do." *Id.* at 264.

70. "A resilient supply system delivers energy to its users via short, robust links. Energy that travels simply and directly from one's own rooftop, or down the street, or across town, is more likely to arrive than energy that must travel hundreds or thousands of miles and be processed and converted in complex devices along the way." *Id.* at 265. "Electricity travels at close to the speed of light and those running the network must make decisions quickly, or have in place devices that make decisions automatically. A few seconds of delay may turn a local perturbation into a multi-state blackout. In an interconnected system, a deviation from normal operations in one region affects all the connections, as well," LEONARD S. HYMAN ET AL., *AMERICA'S ELECTRIC UTILITIES: PAST, PRESENT AND FUTURE* 35 (6th ed. 1997).

71. See STEVEN FERREY, *THE NEW RULES* 260 (2000).

nect many diverse customer load profiles and allow centralized generation equipment to run at higher load factor. These advantages, especially post-9/11, do not so favor centralization.

Analysts argue that a distributed energy system, including increased use of cogeneration, is much less subject to disruption, whether from weather, terrorism, or other factors, than the centralized generation and distribution system employed in the United States.<sup>72</sup> In 2003, the Congressional Budget Office concluded that “Distributed generation, the small-scale production of electricity at or near customers’ homes and businesses, has the potential to improve the reliability of the power supply, reduce the cost of electricity and lower emissions of air pollutants.”<sup>73</sup> Distributed resources have the potential to further reliability requirements because distributed generation occurs throughout the electric system; distributed solutions can be implemented at less cost than central station and transmission-dependent solutions for reliability.<sup>74</sup>

According to the Critical Power Coalition, there is approximately 80 GW of off-grid backup generating capacity installed, equal to about 10% of the U.S. grid’s capacity.<sup>75</sup> In addition, it estimates that there are 25 GW of large uninterruptible power supply equipment in businesses, and another 10 to 15 GW of uninterruptible power supply capacity in smaller desktop-size units in businesses and residences.<sup>76</sup> In addition, there are about 30 million large stand-by batteries installed.<sup>77</sup>

There will be more decentralized resources in our electric energy future. The U.S. Department of Energy estimates that more than 11% of future installed generating capacity will come from distributed generation.<sup>78</sup> It is estimated that on top of the approximately

---

72. See Hisham Zerriffi, Hadi Dowlatabadi, & Neil Strachan, *Electricity and Conflict: Advantages of a Distributed System*, ELECTRICITY JOURNAL, Jan./Feb. 2002, at 57, 58; LOVINS ET AL., *supra* note 43, at 111.

73. U.S. CONGRESS, CONGRESSIONAL BUDGET OFFICE, PROSPECTS FOR DISTRIBUTED ELECTRICITY GENERATION ix (Sept. 2003).

74. Richard Cowart, et al., *State Electricity Regulatory Policy and Distributed Resources: Distributed Resources and Electric System Reliability*, NATIONAL RENEWABLE ENERGY LABORATORY, NREL/SR-560-32498, Oct. 2002, at 6.

75. See *A White Paper on Critical Power*, DIGITAL POWER GROUP, Aug. 2003, at 2; available at [http://www.criticalpowercoalition.org/critical\\_power\\_white\\_paper.pdf](http://www.criticalpowercoalition.org/critical_power_white_paper.pdf) (last visited July 18, 2005).

76. *Id.*

77. *Critical Power Technologies Needed to Bridge Gaps in the Grid, Group Says*, in PLATTS ELECTRIC UTILITY WEEK, Aug. 9, 2004, at 5 – 6.

78. U.S. CONGRESS, CONGRESSIONAL BUDGET OFFICE, *supra* note 73, at 7.

49,000 MW of currently installed cogeneration capacity there is another approximately 163,000 MW of cogeneration potential in the commercial and industrial sectors alone, of which the government estimates that 20% will be realized in the near term.<sup>79</sup>

This will occur for reasons of economics, reliability, and control. Dispersion of generation changes the energy flows of our society. A large number of small units has greater collective reliability than a small number of large units, thus favoring distributed resources.<sup>80</sup> Distributed resources tend to fail less than centralized plants and are faster to fix.<sup>81</sup> A comparison of ten industrial independent power facilities against five comparably sized and constructed utility facilities indicates that the former are more reliable.<sup>82</sup> Independent power projects have demonstrated greater availability and higher capacity factors than comparable utility plants.<sup>83</sup> The robustness of a distributed, on-site, cogeneration-based system, likely fueled by natural gas, results from:

- Reliance on a larger number of small generators, no one of which is critical to supply very large amounts of energy.
- Less reliance on a vulnerable centralized transmission and distribution grid.
- Reliance on the movement of natural gas fuel in the more protected underground pipeline system to the electric generation located and distributed near the demand load center, rather than reliance on more vulnerable above-ground electric transmission infrastructure to distribute electric power to the load. Gas can be stored in pipelines while electricity can-

---

79. *See id.* (utilizing U.S. Department of Energy EIA data from year 2000).

80. LOVINS ET AL., *supra* note 43, at 181. They also reduce reactive power flows by avoiding transformers. *Id.* at 225.

81. *Id.* at 186.

82. *See* Morton M. Smith, *Reliability, Availability, and Maintainability of Utility and Industrial Cogeneration Power Plants*, IEE document 89CH2792.0, Oct. 1989 at 1783 – 87, as discussed in STEVEN FERREY, *THE LAW OF INDEPENDENT POWER* §3:99 (22nd ed. 2004) (finding the mean value of availability for the five utility facilities, ranging in size from 75 to 500 MW was 86.6%. For the ten independent power facilities the availability was 95.6%).

83. NATIONAL INDEPENDENT ENERGY PRODUCERS, *NEGOTIATING RISK: EFFICIENCY AND RISK SHARING ELECTRIC POWER MARKETS* 9 (1992) (noting that independent projects fired by coal average 88 to 90% availability compared with 81% availability for comparably-sized utility-owned coal-fired plants. Independent gas-fired plants show 94 to 96% availability compared to 87 to 92% for comparable gas-fire utility plants.).

not be stored in transmission lines, especially where they are knocked out.<sup>84</sup>

This decentralization reorders the dependency relationship between major suppliers and the consumer of an essential service. Much like the automobile, this can be a significant force for autonomy and decentralization.<sup>85</sup> This has the potential to be a formative force on spatial development, modern society and lifestyle, and institutional evolution, as discussed earlier in this Article.

### I. *Digital Versus Analog: The Branding of Electric Power*

The nature of electricity demand is shifting profoundly in industrial nations. The current electricity infrastructure in the United States is designed to serve historic analog electric load where there is a continuously varying demand and the system is not required to supply digital quality power. In the 21st Century, in a typical modern home, there are as many as thirty microprocessors and sensors in home appliances. Constant and stable digital quality power, with reliability to serve these digital loads, now represents about 10% of total electricity use in the U.S. and is expected to reach 30% of total electricity use by 2020 under business-as-usual conditions.<sup>86</sup>

It has been estimated that the premium value for more reliable service can be a relatively low amount up to \$1,000 per outage or more even for momentary interruptions.<sup>87</sup> Where loss of refrigeration is involved, or business involving digital services are affected, brief in-

---

84. Hisham Zerriffi, et al, *Electricity and Conflict: Advantages of a Distributed System*, ELECTRICITY JOURNAL, Jan./Feb. 2002, at 59 – 60 (noting that over a range of model scenarios, the authors conclude from the model that a distributed system is up to five times less sensitive to loss of load under systematic attack over a range of impacts than the conventional distributed electric system. This analysis focuses primarily on loss of generating capacity, rather than on transmission and distribution system attack. It also does not look at the stability of the natural gas supply system.)

85. JON VAN TIL, LIVING WITH ENERGY SHORTFALLS: A FUTURE FOR AMERICAN TOWNS AND CITIES 107 (1982) ("Other statements have been made to the point that energy shortfall contains within it a set of implications more conducive to decentralization than to reconcentration. Peterson and Hempel have analyzed the decentralizing influence of solar, recycling, and communications technologies and note that each of these technological developments offers an individual the opportunity to withdraw from traditional dependency relationships which have been created by the basic urban institutions of our time: city governments, utility companies, major educational centers and the workplaces of corporate capitalism. . . . There is increasing evidence that dispersed settlement patterns can be combined with what we have previously considered urban levels of quality of life.").

86. Clark Gellings & Richard Lordan, *The Power Delivery System of the Future*, ELECTRICITY DAILY, Jan./Feb. 2004, at 23.

87. SWISHER, *supra* note 48, at 21.

terruptions can cost hundreds of thousands of dollars, or even millions of dollars for pharmaceutical, brokerage and semi-conductor companies.<sup>88</sup> For certain industries, the cost of a one-hour blackout can be many millions of dollars in lost production, lost orders, or lost information.<sup>89</sup>

In the relatively near future, electricity will be disaggregated into different level products so it is not sold as a single commodity. Certain consumers will purchase from suppliers, or provide themselves through self-generation, a higher quality of electricity for certain requirements that demand regular, high quality power supply. For the digital age, this will be a change in the branding of a previously generic service.

#### J. *States as Energy Drivers*

The federal government has not stepped up to many of these challenges. In the void, states have become the leaders in changing the domestic electric energy system in the United States. The frame of significant initiatives in the last 5 years was spawned at the state level. These initiatives include (1) renewable portfolio standards (RPS), (2) system benefit charges and trust funds for renewable power development, and (3) net metering for encouraging dispersed electric generation. The three of these together, or any one of these, are encouraging the energy “pivots” discussed above. Rate disincentives implemented at the state level can negate these incentives. How states encourage or discourage the creation of decentralized dispersed energy sources through various regulatory, subsidy, and metering initiatives, will sculpt the electric energy future.

##### 1. RPS and Trust Funds

Typically, states deregulating their retail electric sectors have implemented renewable portfolio standards and/or trust funds. Fifteen of 21 states in the deregulating vanguard have elected one or both of

---

88. *Id.* at 22.

89. U.S. DEPARTMENT OF ENERGY, STRATEGIC PLAN FOR DISTRIBUTED ENERGY RESOURCES 7 (2000) (noting that this study estimates that the value of a one-hour blackout to a brokerage firm is \$8.5 million. At this cost, the reliability value of distributed generation more than justifies its capital cost. This is because that level of reliability cannot be obtained at any price from the centralized utility grid. There are no substitutes for this. Therefore, the proper trade-off is the loss from disruption and this value should be added to the cost of not having distributed generation.).

these options.<sup>90</sup> Some adopt both concurrently. How each defines an eligible renewable resource varies.<sup>91</sup>

A resource portfolio standard requires electricity sellers and/or buyers to maintain a predetermined percentage of designated and defined clean energy resources in their wholesale supply mix.<sup>92</sup> Renewable trust funds are likely to be less efficient than portfolio standards in promoting the burgeoning renewable power industry. Portfolio standards set a requirement, and challenge market participants to satisfy it in any, and the most efficient, manner possible. By contrast, trust funds create a discretionary gift/subsidy program, causing renewable projects to conform themselves to funding criteria, rather than to take the initiative to operate most efficiently. It is also possible to raid trust fund cash flows; Massachusetts has already withdrawn trust funds for general budget purposes.<sup>93</sup>

Renewable portfolio standards are flexible in that certain technologies can be included in the renewables definition, or certain subgroups of technologies can be targeted for inclusion at distinct levels.<sup>94</sup> The standard allows market competition to decide how best to achieve these standards. The standards become self-enforcing as a condition of retail sale standards for licensure. Excess credits can be tradable; Noncompliant retailers can purchase surplus credits from those who overachieve the standard. Resource portfolio requirements can be applied under any system of wholesale or retail competition, without placing any entities at a disadvantage.

Renewable surcharges and trust funds do not compel the realization of renewable energy goals, as a portfolio standard does. Trust funds subsidize suppliers or consumers, but like many such subsidies, it promotes, but does not compel, targeted technology implementation. However, both are important and utilized in about 30% of the

---

90. Steven Ferrey, *Sustainable Energy, Environmental Policy, and States' Rights: Discerning the Energy Future Through the Eye of the Dormant Commerce Clause*, 12 N.Y.U. ENVTL. L.J., 507, 645 (2004).

91. *Id.* at Table 4.

92. *Id.* at 529.

93. *Bill to End Tug of War Over Mass. 'Green' Trust Would Boost Renewable Purchases*, PLATTS ELECTRIC UTILITY WEEK, Apr. 14, 2003, at 14 (noting that \$17 million was diverted from the trust fund to cover general state budget shortfalls).

94. *See* Ferrey, *supra* note 90, at Appendix (discussing targeted technologies in the states).

states.<sup>95</sup> RPS operates as a condition of the license to do business of otherwise unregulated retail power sellers in the state.<sup>96</sup>

## 2. Net Metering

Net metering is the principal mechanism employed by the states to encourage decentralized and renewable energy technologies. Net metering<sup>97</sup> is the single most potent incentive promoting distributed generation. It is a controversial state initiative that provides an indirect subsidy to certain distributed generation sources, as defined by the particular state.

Net metering is the process by which an electric utility meter for a distributed generator is designed and allowed by law to rotate either forward or backwards depending on which direction (to or from the grid) electricity is flowing at a particular instant. Net metering is adopted in some form in thirty-six U.S. states.<sup>98</sup> Each state has adopted its own unique set of statutes and regulations. Some states allow net metering only for smaller renewable generation, which other states liberalize these eligibility criteria, even including locally produced fossil fuel.<sup>99</sup> States customize net metering eligibility by project size, technology, and type of customer. Some states pay the dispersed generator for excess power sales at either the full retail rate or at avoided cost.<sup>100</sup>

## 3. Exit Fees

Some states, however, dampen the impact of these three promotional tools by imposing either exit fees or prohibitively high stand-by service charges on dispersed generators. Some states allow utilities to

---

95. *Id.* at 524.

96. *See id.* at 529 (discussing how resource portfolio requirement requires that specific electricity sellers and buyers maintain a certain level of designated clean resources).

97. The term "net metering" is the commonly accepted term for this concept; However, states differ in how they describe the same concept. Various phrases used include "net metering," "net billing," "net energy metering," "net energy billing," "parallel billing," "reverse direction metering" and "distributed generation."

98. Steven Ferrey, *"Nothing But Net: Renewable Energy and the Environment, Mid-American Legal Fictions, and Supremacy Doctrine,"* 14 DUKE ENV'L. L. & POL'Y F. 1 (2003) (noting that prior to 2000, the original 30 net metering states were: Arizona; California; Colorado; Connecticut; Delaware; Hawaii; Idaho; Indiana; Iowa; Maine; Maryland; Massachusetts; Minnesota; Montana; Nevada; New Hampshire; New Jersey; New Mexico; New York; North Dakota; Ohio; Oklahoma; Oregon; Pennsylvania; Rhode Island; Texas; Vermont; Virginia; Washington; Wisconsin). *See also* THE GREENPOWER NETWORK: NET METERING, available at <http://www.eren.doe.gov/greenpower/netmetering>.

99. Ferrey, *supra* note 98, at 55 – 65.

100. *Id.*

charge exit fees to customers who depart centralized service for distributed generation.<sup>101</sup> This imposes a large one-time payment on the generating customer to the utility for the privilege of not remaining a customer. This exit fee typically negates the economic benefits of self-generation.

Some utilities with state regulatory concurrence impose high stand-by rates on distributed cogenerators needing back-up power.<sup>102</sup> For a typical customer, stand-by service charges can amount to an additional one-half cent per kWh in generating costs.<sup>103</sup> Stand-by service charges range from zero to \$18.75/kWh/month, raising the cost of generation by as much as twenty percent.<sup>104</sup> These exit fees confiscate the "savings" from self-generation for the utility, rendering largely nugatory the financial benefits of self-generation.

At the state level, state governments have discretion on which of these various incentives or disincentives they will implement. States control whether to allow net metering, whether to institute a renewable portfolio standard, whether to collect a renewable system benefit charge and distribute the proceeds of the resultant trust fund, whether to allow departing customers to be charged an exit fee when they adopt self-generation, and at what levels to set the stand-by power rates for cogenerators and self-generators. These choices are the tools that sculpt the electric energy future. The creative application of these options will decide whether a decentralized, a renewable, or a conventional electric future is promoted. Again, here, there are significant differences between the states promoting alternative energy in their electric spheres, and those clinging to conventional scenarios. There is a pivot in electric technology depending on what and how we promote through existing regulatory mechanisms conventional and renewable technologies.

---

101. See Steven Ferrey, *Exit Strategy: State Legal Discretion to Environmentally Sculpt the Deregulating Electric Environment*, 26 HARV. ENVTL. L. REV. 109, 109–10 (2002).

102. See FERREY, *supra* note 82, for an itemization of all major utility stand-by rates by state.

103. U.S. CONGRESS, CONGRESSIONAL BUDGET OFFICE, *supra* note 73, at 25.

104. See *id.* at 25. A National Renewable Energy Laboratory study concludes that variations in stand-by rates "demonstrate a lack of consistency and an absence of regulatory oversight of [stand-by] tariffs . . . and the lack of appropriate regulatory principles or standards . . . creates uncertainty." *Id.*

### K. *The Dilemma of Deregulation in 40% of States*

What appeared as an unstoppable trend to retail deregulation at the state level at the dawn of the 21st century was brought to a grinding halt by the California electric energy debacle in late-2000-to-2001.<sup>105</sup> A half-dozen states on the verge of deregulating at the time of the California collapse, actually re-trenched and turned back before deregulation was implemented in their states.<sup>106</sup> This has left a deep freeze with 18 states deregulated at the retail level and 32 states still conventionally regulated. There has been no thaw or movement now for more than 3 years and no immediate prospect of change.

This creates several problems. First, independent suppliers in traditionally regulated states are able to sell power into deregulated states, but not vice-versa. Second, because of this checkerboard of regulation, and the lock-in of conventionally regulated utilities in many of the not deregulated states, power is not able to flow to its highest and best use across the nation in interstate commerce, even where transmission capacity is available. Third, the interest of utilities and electric suppliers are counter-poised between regions of the country with retail deregulation (particularly the Northeast) and other traditionally regulated and structured regions of the country. Efficiencies are not being realized and environmental externalities of prodigious fossil fuel combustion in power plants are being exported down-wind to other areas of the country.

Finally, supply-demand imbalances may result. Electricity requires infrastructure to be created and moved to market, unlike some other commodities. In a conventionally structured regulated model, utilities are required to build the vertically integrated infrastructure

---

105. Steven Ferrey, *The Eagles of Deregulation: The Role of the Courts in a Restructured Environment*, 32 ENVTL. L. 297, 299 – 306 (2002).

106. With the collapse of the California deregulated energy markets in 2001, the progress toward deregulation in other states was halted. All of the legislation that originally authorized retail competitive access in the United States was passed between 1996 and 2000. By the end of this period, all 50 states were investigating or moving towards restructuring and competitive retail access; twenty-three states have enacted restructuring legislation as had the District of Columbia, and New York had enacted a restructuring order at the commission level. In fact, there was an increasing momentum toward restructuring, with eight of the seventeen states enacting restructuring legislation doing so in 1999, just before California's problems began in 2000. By March 2001, with California in free-fall, the momentum was immediately reversed: Seven states that had passed restructuring legislation began to postpone or significantly modify their programs. Therefore, at the millennium, sixteen states plus the District of Columbia had proceeded with restructuring, while the other thirty-four states had pulled back. However, those states that proceeded generally are larger states and therefore represent a larger proportion of customers than their mere numeric count.

necessary to accomplish adequate service, with a reasonable reserve margin. The costs of this reserve are rolled into basic service rates. Regulated utilities also have eminent domain powers to get this job done against resistance from communities or individuals. It is akin to an insurance policy against electric facility shortages.

By contrast, in a deregulated state, no individual supplier has a particular incentive to create and maintain a reserve margin. Where power is moved freely across state lines, even a reserve margin established in states surrounding California, such as Nevada, Oregon and Arizona, can collapse if that reserve is consumed across state lines elsewhere.<sup>107</sup> The system as a whole must maintain a reserve margin so that one state's reserve margin is not cannibalized by a neighboring state importing power.

In a deregulated state, there is no regulatory mechanism to ensure this; electricity will be undersupplied by private owners of electric generation. No one owner will want to incur the costs to provide the surplus, for which it is not adequately paid, but is necessary to keep the entire system robust. Perhaps \$50-to-\$100 billion of upgrades is necessary in the twenty-first century. Because the federal government does not have the jurisdiction to step in and arbitrate or cause the upgrade of the interstate transmission system, it does not have the power to make planning and construction decisions in the national interest. Nevertheless, the federal government is responsible for the pricing and terms of all wholesale and interstate power transactions.

For the immediate future, lawyers, regulators, and consumers will have to adapt to the patchwork pressures and constraints that accompany 40% of the country in a deregulated mode, and the remaining 60% in a traditionally structured regulated mode. This creates significant regional battles and confrontations in federal and state energy policy. Longer-term, legally resolving and integrating this now frozen patchwork of various systems is a significant legal challenge. New insights, legislation and regulatory systems will be required to "pivot" this odd reality in the national interest.

#### L. *The Globalization of Global Warming*

Finally, let me reach outside the domestic context of my prior points. Global warming confronts world leaders with the environ-

---

107. See Ferrey, *supra* note 105, at 303 (discussing how several states threatened California with litigation for injuries to their states from the California restructuring debacle).

mental challenge of this century. According to many scientists, every additional ton of carbon dioxide (as well as 5 other “greenhouse gases” or “GHGs”) emitted by the burning of fossil fuels (coal, oil, gas) is warming the planet to potentially dangerous and irreversible levels.<sup>108</sup> Measured against this reality, the demand over the next two decades for more electric power is practically insatiable, especially in developing nations. There is no turning back the strong demand of people in developing nations to have the benefits of progress that electricity fosters:

On a personal level, electricity has been essential in easing the lives of the traditionally disadvantaged half of the humanity as it did away with tiresome domestic labor and offered the possibility of female emancipation.<sup>109</sup>

While the problem is global, the battle on global warming will be won or lost in Asia. Asia is home to 3 of the world’s 4 most populous countries, and 5 of the 6 countries that alone will contribute half of the world’s population growth. Of the current approximately 6 billion in world population, more than half live in just a part of Asia.<sup>110</sup> There are almost two billion people in the world, primarily in South Asia and sub-Saharan Africa, with no access to electricity, who now seek it.<sup>111</sup> Many others in poor countries with *access* to electricity cannot yet afford to purchase it, but in the future they will. This poorest one-quarter of humanity now uses less than 5% of all commercial primary energy, but this proportion will increase dramatically over the next two decades.<sup>112</sup>

Between 1980 and 2002, China’s installed electric generation capacity grew from 65 GW to 353 GW, making it the second largest generating base in the world. World population could reach 8 billion people by 2020 and 9-to-10 billion by 2050. Sixty percent of all future greenhouse gases will be emitted in Asia, more than all 6 other continents combined.

Within 15 years, China alone is expected to double its GHG emissions, and quadruple its GHS output before 2050. This will simply swamp any reductions that the U.S. might achieve if it were to

---

108. Greenhouse gases include carbon dioxide (“CO<sub>2</sub>”), methane (“CH<sub>4</sub>”), nitrous oxide (“NO<sub>2</sub>”), hydrofluorocarbons (“HFCs”), perfluorocarbons (“PFCs”) and sulfur hexafluoride (“SF<sub>6</sub>”). All are measured in CO<sub>2</sub> equivalents, CO<sub>2</sub>e. The Kyoto Protocol regulates emissions in developed countries of these greenhouse gases.

109. SMIL, *supra* note 3, at 134.

110. 1.8 billion people live in East Asia and China and 1.3 billion live in South Asia.

111. INT’L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2002 11 (2002).

112. SMIL, *supra* note 3, at 134.

meet the Kyoto GHG targets. And this is just China. Add the burgeoning GHG emissions from India, with a prodigious growth rate on its way to becoming the most populous nation on Earth, Indonesia, the 4th most populous nation in the world and with a high birth rate, and a multitude of fast developing nations such as Thailand and Vietnam (each already exceeds the populations of major European nations such as France, Britain, and Germany), and the battlefront on global warming is fixed immutably in Asia.

This rapid electric growth is not only an alarm but an opportunity. Alternative renewable energy technologies are available and viable today for electric energy production. There is a choice to fund the higher initial costs of renewable energy systems to meet the future power need. The “pivot” we must make immediately to help developing nations do now with alternative energy will seal our global environmental future. In my next book, due to be published in early 2005, I track exactly what works and what doesn’t, and how we win this important global war.<sup>113</sup>

### III. IMPLICATIONS FOR THE LEGAL FUTURE

Table 1 summarizes these 12 issues, the direction in which they pivot the dimension of electric energy, and the resultant force on society. Admittedly, my list of 12 issues is self-selected and not meant to be comprehensive or inclusive. Notice nonetheless how many of the issues suggest choices of renewable and/or dispersed sources of energy. Notice also how, if the system is “pivoted,” it exercises a decentralizing force on energy supply and social structure.

---

113. FERREY, *supra* note 33.

**Table 1**  
**Issues, “Pivot” Points, and Forces**

	Issue	Pivot Point	Type of Societal Force
1.	Natural Gas Dependence	Increased International Vulnerability	Interdependence
2.	Fossil Fuel Depletion	Renewable Energy Deployment	Democratization
3.	Inefficiency of U.S. Energy Use	Cogeneration	Decentralization
4.	Environmental Degradation	Renewable Energy; Cogeneration	Decentralization; Democratization
5.	Terrorist Threat	Dispersed Generation & Supply	Decentralization
6.	T&D Vulnerability	Dispersed Generation	Decentralization
7.	Move Gas or Electricity?	Dispersed Generation	Decentralization
8.	Need Greater System Reliability	Dispersed Generation	Decentralization
9.	Digital Electric Quality	Dispersed Generation or System Redundancy	Mixed
10.	Inconsistent State-Level Incentives/Disincentives	New Legal Authority	Mixed
11.	Deregulation and Restructuring in only 18 States	New Legal Authority Required	More Competition
12.	Global Energy Markets Environmental Impacts	Deploy Renewable Technologies International	Democratization; Decentralization

Why is renewable energy a democratic force on societal institutions? Human capture of energy is now neither efficient nor prodigious. Energy used by humankind on the earth equals only about 0.01% of the total solar energy reaching the earth. In fact, no nation on earth uses more energy than the energy content contained in the sunlight that strikes its existing buildings every day. The solar energy that falls on roads in the United States each year contains roughly as much energy content as all the fossil fuel consumed in the world during that same year. Therefore, while fossil fuels are quite concentrated in ownership as well as their limited location in certain countries, renewable resources are distributed democratically across the surface of the Earth, in every nation and to the different parts of every nation.

Just as environmental implications are becoming more global, energy issues also are becoming more global: The movement and importation of fossil fuels and the international repercussions of the exponential increase in fossil fuel combustion, are now geopolitical issues. With the de-emphasis of regulation in favor of private market initiatives throughout the globe, it becomes even more important that the laws and regulations which exist are properly designed to provide correct market signals. The role of attorneys implementing law and regulation is more important with the recession of regulation and the emergence of markets, private contract and trade.

It is very important to get the global energy transition right at these several “pivot” points. One global penalty for wrong decisions is the continued proliferation of carbon emissions to the environment. The energy decisions we make today as a global community will largely determine the environment for the next several decades. Because we are on the cusp of an energy transition to more renewable energy sources, and possibly to decentralization of control over power—something that comes seldom more than once every century—the decisions we make today will have long-term implications for world environment, distribution of resources, and standard of living.