Wind turbines and invisible technology: unarticulated reasons for local opposition to wind energy

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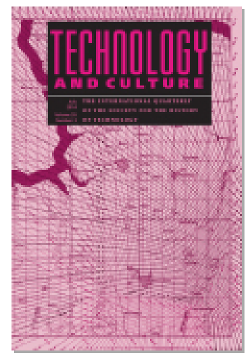

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ESSAY

Wind Turbines and Invisible Technology

Unarticulated Reasons for Local Opposition to Wind Energy

RICHARD F. HIRSH and BENJAMIN K. SOVACOOL

Introduction

Discussions of energy policy frequently focus on economic concerns—and with some validity. Energy consumption has been tied to economic and public well-being for decades, and policymakers have generally felt that economic growth drove increased energy consumption and vice-versa.[1] To create energy policy based largely on economic factors, however, misses important nuances in the way people perceive and pursue energy options. As Langdon Winner presciently noted in 1982, an obsession with economic indicators and cost–benefit analyses among policymakers obscures historical and social concerns that influence energy policy.[2] He observed that the emphasis on improving traditional economic indicators has hidden discussions about power relationships among people, government institutions, and businesses in a manner that hinders the application of democratic principles. In short, Winner argues that energy policy remains shortsighted about noneconomic considerations.

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1. For decades, especially before the 1973 energy crisis, many researchers believed in the strong correlation between overall energy growth and economic growth. See Demand and Conservation Panel of the Committee on Nuclear and Alternative Energy Systems, "U.S. Energy Demand," 144.

2. Langdon Winner, "Energy Regimes and the Ideology of Efficiency."

A series of recent content analyses of leading energy technology and policy journals confirms this point. These studies have noted that the energy policy community continues to downplay the importance of social science methods and concepts, and that many energy problems continue to be described, analyzed, and understood in ways that reflect a preoccupation with an economic model of rational behavior.[3]

As a contrast to this methodology, this essay demonstrates the salience of social science (especially historical) inquiry related to the acceptance of energy technology. To do so, we expand on Winner's insight to argue that decision-makers often fail to appreciate stakeholder concerns that cannot easily be quantified or expressed in economic terms. Consequently, these participants lose effective representation as regulators or legislators invalidate their opposition to policy proposals. Among academics who study "deliberative democracy"—a form of decision-making that provides a moral basis for representatives to involve constituents in governance issues—the discounted dissenters become "objects of legislation" rather than relevant participants in the planning process.[4]

To demonstrate the means by which difficult-to-articulate concerns affect energy policy, we analyze the opposition directed at wind-turbine technology in the United States. Providing context, we first offer a brief history of wind turbines and a discussion of some of their presumed benefits. While we acknowledge several conventional reasons for the opposition—such as avian mortality associated with wind turbines and objections based on aesthetics—we add to the discussion by positing subtle (and perhaps subconscious) explanations for animosity toward the technology. For in-stance, we note that the siting of turbines on rural mountaintops intensifies the already existing conflict between rural landowners and urban customers. Psychologically and symbolically, the turbines sometimes suggest an industrialization of rural residents' environment and the values they perceive as different from those of city folk.

More originally, we opine that opposition to visually obvious and numerous wind turbines stems, at least in part, from the long and successful history of an electric utility system that made its product largely invisible, both in its manufacture and physical manifestation.[5] To many people,

3. See Benjamin K. Sovacool et al., "What About Social Science and Interdisciplinarity?"; and A. L. D'Agostino et al., "What's the State of Energy Studies Research?" Of course, not all analysts focus on the economic approaches to energy policy; others have suggested that risk perception remains predominant among people in making choices about energy policy. See, for example, Christopher A. Simon, "Cultural Constraints on Wind and Solar Energy in the U.S. Context."

4. Amy Gutmann and Denis Thompson, *Why Deliberative Democracy?*, 3. Other discussions dealing with democratic deliberations in the technical realm and the value of expertise in making policy decisions include E. J. Woodhouse and Dean Nieusma, "Democratic Expertise"; and Patrick W. Hamlett, "Technology Theory and Deliberative Democracy."

5. The subject of the invisibility of large-scale sociotechnical networks is elaborated

electricity remains an unseen and unthought-of commodity. But the existence of tall, spinning silhouettes at the top of mountains or a few miles offshore uncomfortably reminds observers that electricity does not emanate magically or inconsequentially from wall sockets; rather, electricity must be created in ways that require painful choices pitting an energy-intensive, high material standard of living against large-scale environmental damage. The previous achievement of the electric utility system in making its infrastructure relatively unnoticed, in other words, sometimes works in an ironic sense to spur objections to wind turbines.

Our exploration of antagonism toward wind-turbine technology has value for historians and nonacademics alike. This essay highlights, in a novel manner, that wind turbines' lack of universal popularity unexpectedly relates to the historical triumph of the electric utility system through the use of centralized and largely unperceived power plants. Receiving little historical study, the concealed features of a technological infrastructure nevertheless play an influential role in people's assessment of policy problems and solutions.[6] By revealing the previously invisible, this essay also offers practical insights to the world of policymakers and energy analysts.

The Environmental Complexities of Wind Energy

At the most uncritical level, wind turbines offer significant potential and real benefits. To the vast majority of Americans who support the technology, turbines contrast favorably with fossil-fuel and nuclear power plants, which require raw materials to be extracted from underground, from mountains, and from ocean beds and therefore cause impacts to natural ecosystems.[7] The conversion of fuels to electricity using conventional

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on in Renate Mayntz and Thomas P. Hughes, eds., *The Development of Large Technical Systems*; Todd R. La Porte, ed., *Social Responses to Large Technical Systems*; Jane Summerton, ed., *Changing Large Technical Systems*; Olivier Coutard, ed., *The Governance of Large Technical Systems*; and Thomas J. Misa, Philip Brey, and Andrew Feenberg, eds., *Modernity and Technology*. Investigations applying this concept of invisibility to energy systems include Jane Summerton and Ted K. Bradshaw, "Towards a Dispersed Electrical System"; James C. Williams, "Strictly Business"; Benjamin K. Sovacool, "Rejecting Renewables" and "The Cultural Barriers to Renewable Energy and Energy Efficiency in the United States"; Patrick Devine-Wright, Hannah Devine-Wright, and Fionnguala Sherry-Brennan, "Visible Technologies, Invisible Organisations"; Alice Grønhøj and John Thøgersen, "Feedback on Household Electricity Consumption"; and Martin J. Pasqualetti, "Opposing Wind Energy Landscapes." Martin V. Melosi's *The Sanitary City* further argues that the delivery of municipal services like electricity and water has become a "hidden function" of local government.

6. As we note below, several scholars have described how technologies become part of people's mindsets over time and thus attract little attention, but few have discussed the practical impact of such views on public perception and policy. Among the wonderful exceptions is Donald Reid, *Paris Sewers and Sewermen*.

7. Polls consistently have shown that Americans generally appreciate the idea of

technologies also yields noxious pollution and unresolved waste-disposal problems. Renewable energy technologies appear attractive because they eliminate impacts like annihilated mountaintops (exposed to enable coal mining) and radioactive by-products, and they make electricity from a never-ending, free supply of natural energy.

On a deeper level, the benefits of wind turbines expand greatly. For example, power providers can often build the devices more quickly than larger-capacity conventional generating plants, thus enabling them to meet incremental demand growth with less economic risk.[8] And when considering all the costs of power-generation technologies (including so-called external costs, such as the health expenses of people exposed to polluted air or the financial toll of climate change), wind turbines often excel, beating most conventional sources, such as fossil-fuel power plants.[9] Use of wind turbines also means less consumption and pollution of water resources—a real concern, since about half of U.S. water use involves producing electricity in thermoelectric plants.[10] Furthermore, the employment of wind energy systems diversifies the fuel mix of utility companies, thereby reducing the danger of fuel shortages, fuel cost hikes, and power interruptions.[11]

For many of these reasons, along with policy initiatives in several countries that have helped wind technology mature since the late 1970s, installation of wind turbines has expanded dramatically. In the United States, the aggregated electrical capacity of wind turbines grew from 240 megawatts (MW) in 1983 to 2,579 MW in 2000, 16,823 MW in 2007, and 46,919 MW at the end of 2011.[12] For comparison, the installed capacity of all forms of generation plants totaled 621,100 MW in 1983, 811,700 MW in 2000,

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renewable energy. In March 2013, for example, the Gallup organization reported that 71 percent of Americans think that the country should place more emphasis on wind energy. See Gallup, Inc., "Americans Want More Emphasis on Solar, Wind, Natural Gas."

8. Benjamin K. Sovacool and Charmaine Watts. "Going Completely Renewable."

9. Benjamin K. Sovacool, "Renewable Energy" and "Valuing the Greenhouse Gas Emissions from Nuclear Power."

10. U.S. Geological Survey, "Estimated Use of Water in the United States in 2000." See also Benjamin K. Sovacool, "Running on Empty"; and Sovacool and Kelly E. Sovacool, "Identifying Future Electricity–Water Tradeoffs in the United States" and "Preventing National Electricity-Water Crisis Areas in the United States."

11. John Christensen et al., "Changing Climates," 18.

12. These data describe the nameplate capacity of the machines, a number that usually refers to the maximum rated output of a generator. For wind turbines, that capacity is reached when the wind blows at the optimal speed for their specific design. At lower wind speeds, the power output (in megawatts) declines and the so-called capacity factor drops, typically to about 30 to 40 percent, even in areas of good wind resources. Traditional fossil-fuel and nuclear power plants run at full capacity for long periods of time (operating as "base-load" units), thus yielding capacity factors of 90 percent or higher. Opponents often point to wind turbines' lower capacity factors and their intermittent power production as major drawbacks. See AWEA, "American Wind Energy Association Annual Wind Industry Report, Year Ending 2008," "AWEA 2008 Annual Rankings Report," and "US Wind Industry Fourth Quarter 2011 Market Report."

994,900 MW in 2007, and 1,054,800 MW in 2011.[13] Although still remaining a small percentage of overall generating capacity, wind-based generation contributed to about one-quarter of newly installed American electricity-generating capacity in 2010.[14] Looking to the future, electric utilities expect to add more wind energy to their portfolios over the next decade than any other source—twice as much as natural gas–fired power plants, the second largest.[15]

Wind-generated power also has become cheaper. A survey of 128 American wind projects in 2007 revealed production costs of less than 5 cents per kilowatt-hour (kWh), making wind turbines more attractive than natural gas in many markets at the time.[16] Worldwide, demand for emissions-free electricity has driven wind-turbine sales. Global wind capacity grew from 6,100 MW in 1996 to 120,291 MW in 2008, and to 237,669 MW in 2011.[17]

Of course, a more holistic look at wind-turbine technology highlights valid concerns that remind us that all electricity-generation technologies engender environmental consequences. Despite their dependence on a virtually infinite and clean source of energy, wind turbines require the construction of service roads to the devices and installation of a network of wires and transmission lines to get the power into the "grid," which connects to almost all customers. To harvest the abundant wind resources at Buffalo Ridge in Minnesota, for example, Xcel Energy constructed a set of transmission lines from 2003 through the end of the decade.[18] Although

13. U.S. Department of Energy, Energy Information Administration, *Annual Energy Review*, table 8.11a, "Electric Net Summer Capacity."

14. AWEA, "2010 US Wind Industry Market Update." See also U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 2010*, table 1.5, "Capacity Additions, Retirements and Changes by Energy Source, 2010." Wind power made up 42 percent of electricity generating-capacity additions in 2009, and at the end of 2010, planners anticipated another 258 gigawatts (GW) of wind-power capacity—more than six times the existing capacity—to be installed in coming years. See Ryan Wiser and Mark Bolinger, *2010 Wind Technologies Market Report*, iii.

15. Ibid., iv. Some of the enthusiasm for wind may be dispelled by the growing use of low-cost natural gas for power generation. See Rebecca Smith, "Can Gas Undo Nuclear Power?" "Rush to Natural Gas Has Coal-Fired Utilities Seeing Red," and "Turning Away from Coal."

16. Mark Bolinger and Ryan Wiser, "Wind Power Price Trends in the United States." The lower cost benefits accrue, in part, from a U.S. federal tax credit of 2.2 cents per kWh received by wind developers for the first ten years of a project's life. See U.S. Congress, *Energy Policy Act of 1992*.

17. Global Wind Energy Council, *Global Wind Report*, 15. This report notes, for example, that in 2011, China had more wind-turbine capacity than the United States (approximately 62,364 to 46,919 MW). In 2011, the countries with the most installed wind capacity were China (26.2 percent of world share), United States (19.7 percent), Germany (12.2 percent), Spain (9.1 percent), and India (6.8 percent) (ibid., 11–12).

18. Minnesota Public Utilities Commission, "In the Matter of the Application for Certificates of Need for Three 115 kV Transmission Lines in Southwestern Minnesota"; Xcel Energy, "State's Largest Wind Farm, Transmission Line Dedicated."

many people expected uncompromised environmental and economic benefits to accrue from the use of wind power, the installation of transmission lines nevertheless caused harm to the natural ecosystem and raised concerns about lowered property values.[19]

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Wind turbines incur other serious environmental costs. Opponents point to avian mortality as among the most critical. Near the relatively small machines installed in the 1970s and ’80s (rated at around 100 kilowatts [kW]—one-tenth of a megawatt), birds often collided with fast-moving turbine blades, support structures, towers, and associated wires that bring the power to the grid. Even close to newer turbines, whose blades turn more slowly than those of the first-generation machines of the 1970s, birds die occasionally during migratory flights, and especially when turbines operate in poor weather and at night. Bats also suffer when they fly into the flow pattern of turbine blades, where reduced air pressure disorients them and causes internal hemorrhaging.[20] Lights required by the Federal Aviation Administration to warn aircraft can pose a further problem if they attract insects on which bats feed, or if they confuse night-flying birds. To address the issue of avian mortality, some turbine operators shut down their machines in poor weather, at night, and during periods of known migrations. Responding to similar concerns, the U.S. Department of Interior has drafted guidelines for minimizing impacts to wildlife through improved site selection, construction, and operation of energy facilities.[21]

Other Conventional Concerns

Opponents of wind turbines also point out that the machines’ presence interferes with people’s pursuit of a host of activities. Some of the best offshore wind potential in the United States, for example, exists along the eastern seaboard—on coastlines valued for their unblemished views, abundant fishing resources, and recreational uses.[22] Onshore turbines, mean-

19. Michelle F. Bisonnette, Angela G. L. Piner, and Pamela J. Rasmussen, “Getting the Crop to Market.” The realization that all energy choices involve trade-offs is neither original nor modern. More than thirty-five years ago, Robert J. Budnitz and John Holdren observed that “no existing or proposed energy technology is so free of environmental liabilities as to satisfactorily resolve the central dilemma between energy’s role in creating and enhancing prosperity and its role in undermining it through environmental and social impacts.” See Budnitz and Holdren, “Social and Environmental Costs of Energy Systems,” 579. According to Arpad Horvath, “[o]ne researcher even jokingly commented that modern resistance toward any energy project is so strong that ‘not in my backyard,’ or NIMBY, is rapidly turning into ‘build absolutely nothing anywhere near anything,’ or BANANA” (“Construction Materials and the Environment,” 182).

20. Erin F. Baerwald, Genevieve H. D’Amours, Brandon J. Klug, and Robert M. R. Barclay, “Barotrauma is a Significant Cause of Bat Fatalities at Wind Turbines.”

21. U.S. Department of the Interior, “Salazar Announces Additional Steps toward Smarter Development of Renewable Energy on U.S. Public Lands.”

22. Benjamin K. Sovacool and Richard F. Hirsh, “Island Wind-Hydrogen Energy.”

while, have sometimes spurred opposition because they interfere with electromagnetic transmission (for example, radio and television broadcasts and radar signals). In certain circumstances, they can also create annoying, low-frequency sounds, as well as the flickering shadows produced by a turbine's blades when they come between the sun and observers in the line of sight.[23] Some of the most notable and well-organized opposition movements for land-based and offshore turbines have occurred in Massachusetts—in Falmouth, where turbines have already been built, and offshore, where construction has not yet begun.[24]

Beyond—or in a way, above—these concerns, opposition to wind turbines often arises because some people disapprove of the presence of the technology in the landscape. For those living near proposed towers, this complaint can be described within the framework of the "not in my backyard" (NIMBY) concern—namely, the opposition of residents and communities facing the unwelcome development of a disruptive public-works project in their neighborhood.[25] These people have lived for years (or generations) with unobstructed "viewscapes," defined by one scholar as "a visual connection that occurs between a person and the spatial arrangement of . . . landscape features."[26] As part of criticism that the NIMBY concept may have little explanatory value, psychologists have begun to focus on notions of "place attachment" and "place identity" to explain emotional and behavioral connections between people and the geography they inhabit, as well as for their opposition to disturbance of that geography.[27] They cherish the peaceful, harmonious connotations of the natural environment and do not want to lose these important elements in their lives. Likewise, people who acquire land in rural areas or by the ocean often consider the natural viewscape as a key component of their purchase's economic and aesthetic value.[28]

More subtly, some people object to the altered sense of the natural environment and the juxtaposition of the urban-industrial experience in

23. Florian Krug and Bastian Lewke, "Electromagnetic Interference on Large Wind Turbines." For a general review of these problems, see Suzanne Rynne, Larry Flowers, Eric Lantz, and Erica Heller, eds., "Planning for Wind Energy." Shadow flicker is described in American Wind Energy Association, "In the Public Interest."

24. Sean Corcoran, "The Falmouth Experience." The offshore wind debate in Massachusetts has been explored in Wendy Williams and Robert Whitcomb, *Cape Wind*; and Pasqualetti, "Opposing Wind Energy Landscapes."

25. Michael Dear, "Understanding and Overcoming the NIMBY Syndrome," 288; Patrick Devine-Wright, "Place Attachment and Public Acceptance of Renewable Energy."

26. Lise Burcher, "Urban Character and Viewscape Assessment."

27. See, for example, Maarten Wolsink, "Invalid Theory Impedes Our Understanding"; and Patrick Devine-Wright, "Beyond NIMBYism." See also Devine-Wright and Yuko Howes, "Disruption to Place Attachment and the Protection of Restorative Environments"; Marino Bonaiuto, Giuseppe Carrus, Helga Martorella, and Mirilia Bonnes, "Local Identity Processes and Environmental Attitudes in Land Use Changes"; and Irwin Altman and Setha M. Low, eds., *Place Attachment*.

28. Paul M. Van Auken, "Seeing, not Participating," 522.

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the wilds of nature. Commenting on the multiplication of wind turbines in California during the early 1980s, one regional planner observed that "[o]nce-friendly pastoral scenes now bristle with iron forests."[29] A *Los Angeles Times* reporter noted, with similar scorn, that the thousands of turbines built in Altamont Pass, California, look like "battalions of exoskeletal outer space creatures." "[E]erie to behold," he wrote, the contraptions struck him as "towering, stilty-looking, at once gawky yet graceful. Their legs are frozen in concrete, stationary but seemingly kinetic."[30] Over the years, wind turbines have largely dispensed with the tripod, lattice structure, usually replaced by single ("monopole") hubs to blend in better with the natural environment. However, they have also become much larger: a 2.3 MW Siemens turbine sports blades that reach 131 meters into the sky, and its rotors sweep through a distance longer than the wingspan of a Boeing 747 aircraft.[31] (By comparison, high-voltage, 765-kilovolt transmission towers rise only about 45 meters.[32]) Unlike conventional fossil-fuel power plants, which usually find homes in places already zoned for manufacturing activities, wind turbines must be located in open, "natural" space where they can exploit forceful wind currents. They often elicit a negative response because they do not fit into a preexisting sense of where similar large-scale industrial technologies belong.[33]

Symbolic Value of Turbines

Like other technologies, wind turbines have great symbolic value, which make the devices both attractive and repulsive to various stakeholders. Often, policymakers do not consider the significance of these symbolic meanings, largely because few people express them cogently. On the one hand, wind turbines have become popular symbols of progress, modernity, and environmental consciousness; they serve as backdrops to advertisements of environmentally preferable hybrid vehicles, such as the Toyota Prius, and even beauty products. (Aveda claims to be "the first beauty company manufacturing with 100% certified wind power."[34]) Political candidates frequently brandish campaign advertisements with images of wind turbines, presumably hoping to enhance their claims as forward-looking environmental stewards.[35] Companies that seek to reduce traditional en-

29. Sylvia White, "Towers Multiply, and Environment is Gone with the Wind."

30. Jerry Belcher, "Electric Power," B1.

31. National Renewable Energy Laboratory, "Multi-Megawatt Turbine Research."

32. Electric Transmission America, "Looking Towards the Future."

33. Robert D. Kahn, "Siting Struggles," 23.

34. See photographs of Prius cars and wind turbines at http://www.autoblog.com/photos/2011-toyota-prius/#4032461#photo-4032469; Aveda's photos are at http://www.aveda.com/discover/acting_responsibly.tmpl.

35. Examples include John McCain's 2008 "Ohio Jobs" campaign advertisement,

ergy consumption, meet corporate and customers' sustainability goals, and enhance their images also turn to wind turbines occasionally, as Wal-Mart has done by installing small turbines near some stores.[36] Vail Resorts, the owner of several ski and mountain areas in the western United States, likewise boosted the company's environmental credentials by publicizing, in 2006, its commitment to purchase wind-power credits to offset all of its energy use.[37] For similar reasons, cereal manufacturers, fossil-fuel firms, banks, and other companies have employed iconic images of wind turbines.[38] In 2013, the U.S. Postal Service commemorated Earth Day with its wind-turbine cancellation mark[39] (figs. 1–2).

On the other hand, huge wind turbines have gained a different symbolic meaning to many people, as the devices intrude on what had been a relatively unspoiled and natural environment. The turbines—especially the hundreds of machines that populated California's Altamont Pass in the 1980s—represent an industrialization of the hills that some rural residents want contained in cities. After all, urbanites have a history of adopting unusual and alien forms of architecture.[40] Despite initial opposition, for example, Parisians took pride in the Eiffel Tower as a symbol of modernity and technological prowess.[41] Skyscrapers in major cities also connote progress, economic activity, and stylish novelty. In 2000, a British company built the Ferris wheel–styled London Eye, which reaches a height of 135 meters and is described, by its owner, as "an iconic landmark and a symbol of modern Britain."[42] These alien objects may fit into the culture and lifestyle of citygoers, but according to many people, they do not belong in the pristine rural landscape. Using a similar logic, residents of the isolated Scottish Isle of Lewis opposed the introduction of as many as 181 turbines that would have reached 140 meters in the sky. Proud of the isle's 8,000-year-old history of habitation based on agriculture and animal husbandry, opponents

available at http://elections.nytimes.com/2008/president/advertising/ads/6712751—john-mccain-ohio-jobs; and Barack Obama's 2008 "The Hands That Built this Nation" campaign ad, available at http://elections.nytimes.com/2008/president/advertising/ads/6603686—barack-obama-hands.

36. "Sam's Club First U.S. Retailer to Install On-Site Micro-Wind Farm—Wal-mart is Next"; Julie Schmit, "Going Greener."

37. Tom Kenworthy, "Vail Resorts to Offset Energy Use with Wind Power Credits." With little fanfare, the company decided to suspend its wind-power purchases in 2009, instead contributing funds to restore forest lands that had been devastated by fires; see "Vail Resorts to Stop Buying Wind-Energy Credits."

38. Examples of wind turbines used in advertisements can be found on Paul Gipe's website "Wind-Works" (see his photos under "Cultural Icons Featuring Wind Turbines"). See also "Coke Leads Movement for Clean Energy Billboards."

39. The U.S. Postal Service cancellation mark did not please everyone; see Tom Steward, "Earth Day Postmark Stirs Ups Wind Opponents."

40. Robert W. Righter, "Exoskeletal Outer-Space Creations," 19.

41. William Thompson, "The Symbol of Paris."

42. EDF Energy, "London Eye."

FIG. 1 Box of MOM's Best Cereals (2013). (Source: Copyright © MOM Brands, Minneapolis, reprinted with permission.)

objected to the "weakening of the cultural roots and conservative lifestyles that people have established there," despite the abundant wind resources that make the turbines' location so opportunistic. If completed, the project could have supplied about 7 percent of Scotland's electricity needs.[43]

Exacerbating the conflict between values, rural residents often feel that turbine construction results from increased power demand incurred by the inhabitants of large cities. Since rural customers do not (in aggregate) use as much electricity, they resent the fact that they suffer the consequences caused by turbine installation while urbanites gain the benefits of increased

43. Pasqualetti, "Opposing Wind Energy Landscapes," 910.

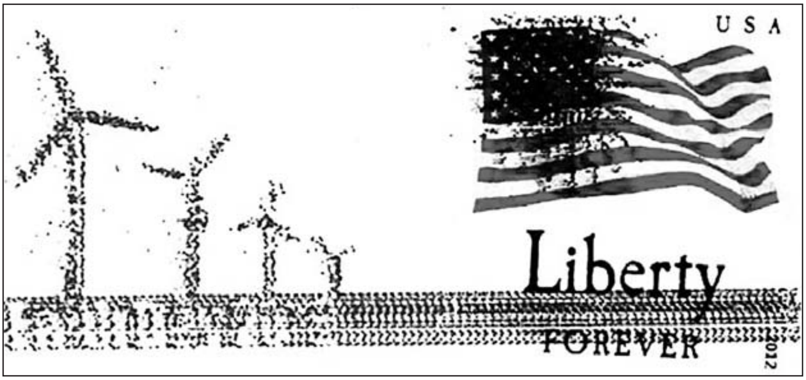

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FIG. 2 Cancellation mark of U.S. Postal Service stamp commemorating Earth Day, April 2013.

power supply. Arguably ethical, the situation imposes the costs and potential mishaps upon one set of the population while another group reaps the benefits. In a related manner, rural people often feel that they have little sway in the policy-making, permitting, or siting processes—processes that city developers (and their hired consultants and lawyers) use to exploit rural resources.[44] In short, wind turbines sometimes inflame preexisting social and economic conflicts between urban and nonurban residents, reflecting an inner struggle that counterposes the progressive values of modern life against the conservative virtues of rural existence.

Of course, one must avoid generalizing the views of all country folk. In many rural communities, people have become accustomed to resource extraction because of benefits that accrue to stakeholders, such as extra income for farmland owners, increased real-estate tax revenue for municipal governments, and greater employment opportunities. Among some Midwestern farmers, the placement of wind turbines on flat, monotonous, and wind-swept properties signals modernity and progress while also allowing them to reap royalties or rent payments from turbine operators. Rather than viewing turbines as a symbol of industrialization blighting a bucolic rural landscape, both likeminded farmers and nonfarmers in these areas view wind turbines as the latest version of state-of-the-art farm equipment rendering the land more productive.[45]

44. Martin J. Pasqualetti, Paul Gipe, and Robert W. Righter, eds., *Wind Power in View*, 10–12. These concerns are also exacerbated by views that rich city dwellers impose themselves on their poor rural cousins, who have less at stake in the turbines than do urban business people. See Pasqualetti, "Opposing Wind Energy Landscapes," 914–15.

45. Martin J. Pasqualetti, "Wind Power," 22–38. The observation comes from Virginia Tech graduate student (in science and technology studies) Josh Brinkman, whose family has farmed large expanses in the Midwest for generations. See also Jacob Sowers, "Fields of Opportunity." Brinkman and one author of this essay (Hirsh) are pursuing

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Whether rural residents loath or love wind turbines, their attitudes often depend on their perceptions of the natural environment and progress—concepts that landscape scholars, historians, geographers, and psychologists recognize as socially constructed.[46] Put more simply, people's notions of technology, as placed within nature, change.[47] While some observers may define natural as meaning pristine and untouched by humans, most others accept a certain (and often large) amount of intervention within their interpretation of it. The English countryside, for example, still remains largely desirable, despite centuries of human planning, as historian Robert Righter observes:

> Winding roads, curving fences, wooded hills, hedge-rows, and green pastures combine to render our ideal of an aesthetic landscape. The combination of natural elements gives the illusion that nature does the planning here. Obviously, there is human order, but it is subtle, hidden from view. What does come to mind is harmony: an appealing symbiosis between people and nature. It is as if people and the land have coexisted here in the past, in the present, and will continue in the future.[48]

Leo Marx, the perceptive social historian of technology, observed that Americans in particular had happily accepted similar "improvements" in nature. Telegraph wires and railroad tracks streaming across the expansive continent (as portrayed in John Gast's "American Progress" painting of

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further research on Midwestern farmers' enthusiastic support of wind turbines on their properties.

46. In recent decades, academics have focused more scrutiny on how humans perceive and deal with nature, and how they use technology to mediate it. For example, psychologist Peter H. Kahn has offered evidence suggesting psychological and biological predispositions for people to "connect" with nature. His 1999 book *The Human Relationship with Nature* highlights studies suggesting that "humans choose landscapes that fit patterns laid down deep in human history on the savannas of East Africa," and that people who "affiliate with nature" tend to have fewer illnesses and generally feel better (2–3). Sherry Turkle, meanwhile, has written about the relationship between humans and technology, although she focuses more on how the technology mediates relationships among people. See, for example, Turkle's *The Second Self* and *Alone Together*. Con-servation and environmental psychologists have asserted that people make emotional connections with nature, which obviously affects their views of how it should be developed. See Carol D. Saunders, "The Emerging Field of Conservation Psychology," and issues of the *Journal of Environmental Psychology*, which started publication in 1981 and defined the interdisciplinary field as "that area of psychology which brings into conjunction and analyzes the transactions and interrelationships of human experiences and actions with pertinent aspects of the socio-physical surroundings" (David V. Canter and Kenneth H. Craik, "Environmental Psychology," 2).

47. For discussions of the rich set of interactions among nature, landscape, and technology, see David E. Nye, ed., *Technologies of Landscape*; and Martin Reuss and Stephen H. Cutcliffe, eds., *The Illusory Boundary*.

48. Righter, "Exoskeletal Outer-Space Creations," 29.

1872) and factories with belching smokestacks often connoted progress and the enhancement of nature rather than its defilement.[49] Likewise, to Great Depression–era rural inhabitants, the erection of distribution lines through the countryside signified the unambiguous improvement of life that accompanied electrification. The editors of *Rural Electrification News*, for example, exultantly published photographs of power lines during the 1930s with captions like "a pole-line is rapidly becoming a symbol of a progressive rural community" and "the rural line reflects a prosperous countryside."[50]

During the Depression, the environmental consciousness of most Americans did not compare to that of the 1980s and later. Earlier, people considered many elements of valued infrastructure as symbols of modernity or of yielding benefits that vastly outweighed their aesthetic costs. Perhaps they retain the same perspective when holding generally positive views toward the construction of tens of thousands of cell-phone towers during the last few decades. While one can debate whether people interpret cell phones as progressive and wind turbines as regressive, the two technologies differ significantly in the fact that the latter demonstrate movement. Just like other animals, humans perceive moving things as more significant than static entities. Because of evolutionary pressures, most animals detect motion as a means of identifying biologically important stimuli, such as predators, potential prey, or their own kind.[51] Consequently, we direct our eyes more instinctively toward moving turbine blades than to cell-phone towers, causing more psychological impact from the former. To some people, the spinning blades serve as annoying distractions and symbols of rural–urban conflicts, along with subtle, difficult-to-express antagonisms toward exploitative urbanites.

The Effect of the "Invisible" Electric Utility System

Wind-turbine advocates suffer from the disadvantage that their favored technology remains particularly visible in a way that other elements of the electric utility system do not. Consequently, the hardware reminds people (or introduces them to the notion) that their existence in a technologically intensive world requires them to depend on the plentiful supply of electricity—an almost magical and largely unsensed substance. Moreover, for better or worse, the system that produces and distributes that substance has remained essentially invisible as well, further clouding the popular understanding about electricity and the social, economic, and political challenges

49. Leo Marx, *The Machine in the Garden*; Edward Tenner, *Why Things Bite Back*, 154.

50. See the photographs in *Rural Electrification News*, issues January/February and April 1936.

51. Winand H. Dittrich and Stephen E. G. Lea, "Motion Discrimination and Recognition."

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involved in its production and distribution. The prominent existence of wind turbines destroys that invisibility and causes people to confront difficult choices.

For the most part, the sources of electricity—power plants—have been exiled to rural, low-population regions of the country, although not always. When electric utility systems emerged, soon after Thomas Edison demonstrated one in New York City in 1882, generation stations remained near their customer bases. Producing direct current, the first plants could distribute power no farther than a few miles from their sources, thus requiring dirty, throbbing, and noisy stations to locate conspicuously within cities. The situation changed, however, as evolving alternating current and transformer technologies enabled the transmission of power over great distances. Power could, therefore, emanate from remote hydroelectric generators, as demonstrated in 1896 by a plant at Niagara Falls, twenty-six miles away from its predominant electricity consumers in the city of Buffalo.[52] The growing use of steam-turbine generators in the early part of the twentieth century allowed utility companies to generate increasing amounts of power from fossil-fuel-burning plants that yielded huge economies of scale. Throughout the century, such plants employed turbine generators that grew from 3.5 MW capacity in 1901 to 1,000 MW in 1965, and to 1,300 MW in 1973.[53]

Taking advantage of the increasingly efficient transmission system, power companies located these plants far from "load centers" (mostly cities), where they could more easily obtain land, water resources, and raw materials than in urban locations. The American Electric Power Company, for example, installed a series of 1,300-MW units in Winfield, West Virginia, a town of 2,301 people (according to the 2010 census) within a county having a population of 55,486 and located about twenty-five miles from the state capital.[54] Consequently, few people—except those living near the units—had direct sensory experience with the power plants themselves, thus making them largely unobjectionable. The establishment of big power plants in isolated locations harmonizes with the conclusion made by landscape architect Robert Thayer, that "[a]t the perceptual level, the less conspicuous the technological landscape, the more it is likely to be valued by the general public."[55]

Of course, even urban dwellers know about the wires and poles (and transmission towers, farther from the city) that bring them power. But as social scientists have noted, these static devices often become lumped together in most people's minds as part of the natural landscape, just like

52. Thomas Parke Hughes, "The Science-Technology Interaction," 647.

53. Richard F. Hirsh, *Technology and Transformation in the American Electric Utility Industry*, 37, 64, 94.

54. U.S. Census Bureau, "2010 Census Data."

55. Robert L. Thayer, *Gray World, Green Heart*, 128.

other technologies that make up important technological (and also invisible) elements of modern technological infrastructures.[56] Cultural historian David Nye observes, for example, that environments consisting of once-innovative hardware and technological infrastructure become natural because they existed since the onset of people's consciousness, forming "the habitual perception of a sustaining environment that is taken for granted as always there."[57] In a similar way, historian James Williams explains that as people use technological systems in their everyday lives, they quickly accept them into their psyches as part of the natural landscape. As such, the tools and devices become essentially invisible, rarely engendering comment about their places in society or in the environment.[58]

Through this process of "naturalization," vast technological networks become largely unseen. Expressed differently, most people simply do not realize that important technological systems, such as those that bring water to their homes and take sewage away from them, exist at all.[59] The systems no longer retain status as technology, or at least as things that deserve special attention. As historian Paul Edwards observes:

> The most salient characteristic of technology in the modern (industrial and postindustrial) world is the degree to which most technology is not salient for most people, most of the time. . . . [T]he fact is that mature technological systems—cars, roads, municipal water supplies, sewers, telephones, railroads, weather forecasting, buildings, even computers in the majority of their uses—reside in a naturalized background, as ordinary and unremarkable to us as trees, daylight, and dirt. Our civilizations fundamentally depend on them, yet we notice them mainly when they fail, which they rarely do.[60]

In other words, most infrastructural systems, such as the one that brings us electricity (as we now argue), have become essentially invisible.[61] And, of

56. The invisibility of infrastructures also appears to be common in Great Britain; see Elizabeth Shove and Heather Chappells, "Ordinary Consumption and Extraordinary Relationships," 57.

57. David E. Nye, *Consuming Power*, 7–8.

58. Williams, "Strictly Business," 626–30; see also James C. Williams, "Understanding the Place of Humans in Nature."

59. Psychologists often discuss this "naturalization" process by using the term *habituation*, in which repeated applications of a stimulus (such as an unusual sound) result in fewer responses and eventual immunity to it.

60. Paul N. Edwards, "Infrastructure and Modernity," 185.

61. Such systems often become visible only when the infrastructure fails, as during prolonged blackouts resulting from major storms like Hurricane Katrina in 2005 and Hurricane Sandy in 2012. At least one ethnographer includes, as a critical element of the definition of infrastructure, the notion that it remains invisible until something wrong occurs: "The normally invisible quality of working infrastructure becomes visible when it breaks: the server is down, the bridge washes out, there is a power blackout" (see Susan Leigh Star, "The Ethnography of Infrastructure," 382). Similarly, in *The Sanitary City*,

course, invisible things benefit from having no unpleasant (or intellectually jolting) significance, as geographer Martin Pasqualetti notes:

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> An out of sight, out of mind pattern misleads the public by suggesting that the environmental costs of electricity are less than they actually are. . . . [A]s distance, technology, and our urbanized lifestyle came to cushion us from the direct environmental costs of energy, we become increasingly less aware and eventually less tolerant of the intrusions of energy development on our personal space.[62]

Other scholars have looked at naturalized technologies in a different manner, one that also has relevance for the popular understanding of electricity. According to historian Kevin Borg, some infrastructural hardware systems have become "ontologically opaque," showing little connection to "human physiology and perception." Such complex technologies remain "by their very nature epistemologically obscure," having no "direct sensate experience at their working level." They are rarely understood "in the traditional, visceral sense that one knows what a chair is and how it works."[63]

Although other technologies—even those emerging during the nineteenth century, such as the telegraph and the telephone—shared some ontological opacity, electricity remains perhaps the best example, since it serves as the driving medium for these others to operate. When trying to explain the essence of electricity to the layman, experts often resort to analogies of flowing water. Nevertheless, the analogy has its faults, and electricity remains somewhat mysterious and ethereal. Unlike water, electricity cannot be perceived in the normal fashion as something that has weight or other common physical dimensions.[64]

Melosi writes that "[u]nfortunately, it takes a major disruption like an earthquake—or hurricane—to demonstrate graphically the importance of the streets and alleys, bridges, power and communications networks, water and sewer lines, and waste-disposal facilities to urban survival" (x). On the other hand, the visibility of infrastructure remains somewhat limited to the downed lines that brought power to homes and businesses, and few people gain an understanding of other infrastructural elements, such as the power plants that generate electricity in the first place. In other words, people only become aware of the broken distribution lines rather than the entire infrastructural system. While individuals may seek solutions to avoid similar mishaps in the future, such as installing underground conduits, they rarely consider solutions that involve the generation of electricity, such as the use of small-scale, localized powers plants that minimize the need for distribution lines altogether. See, for example, David J. Unger, "Hurricane Sandy Cuts Power for Millions." The benefits of so-called distributed generation systems can be found in Richard F. Hirsh and Benjamin K. Sovacool, "Technological Systems and Momentum Change."

62. Martin J. Pasqualetti, "Morality, Space, and the Power of Wind-Energy Landscapes," 384–86.

63. Kevin Borg, "The Mechanic's Lost Senses," 22.

64. Ibid.

Poor Public Understanding of Electricity

These insensate characteristics of electricity extend to its opacity as an economic entity. While academics and industry insiders may think of electricity in traditional terms as an economic commodity, most consumers do not; in fact, they generally do not view electricity as a product they buy in the classical sense, nor do they know how much it costs. In most cases, customers receive bills for electricity weeks after they have used it, so they have no sensory connection between their purchase of power and its use.[65]

Indeed, the effortlessness with which most consumers receive energy in their homes reflects a dramatic shift from formerly active energy producers to presently passive energy consumers. In the 1800s, for example, most inhabitants heated their homes with wood stoves, meaning that they also assumed responsibility for chopping and stacking wood. This labor-intensive form of heat production preceded the use of the coal-fired furnace, which saved some effort by having coal delivered by others; still, users needed to shovel the coal into a furnace, usually on a daily basis, and the routine made the householder aware of dwindling fuel supplies. The oil-fired furnace, which sometimes came next, no longer required daily tending and relied upon storage tanks so users did not need to monitor closely their fuel supply. Finally, the modern-day natural gas or electric furnace removes almost all human involvement in the production of heat apart from flicking a switch. Consequently, the tasks of fuel collection, distribution, and delivery (along with energy use) have become painless, concealed, and largely unnoticeable.[66]

Moreover, the household experience with electricity differs from that of other purchases; for example, when buying groceries, consumers know (from the shelf tag or marked price) how much each item costs. Likewise, although telephone customers receive a bill after they have used the service (as they do for electricity), they can review it to verify the cost and duration of each call. Even when encountering energy in other situations, such as when purchasing gasoline for their vehicles, individuals have a direct experience in which they connect the quantity of their purchase to a specific result, such as being able to drive a certain distance.

But because electricity powers so many applications within the house, such as lighting, ventilation, refrigeration, heating, and entertainment, people rarely understand the linkages between electrical use and traditional economic indicators. The lack of a direct connection between power

65. The invisibility of electricity as a consumer good is explored in Corinna Fischer, "Feedback on Household Electricity Consumption," in which the author notes that "electricity differs in significant ways from other consumer goods. It is abstract, invisible, and untouchable. It is not consumed directly but indirectly via various energy services" (80).

66. Paul C. Stern and Elliot Aronson, *Energy Use*, 35–36.

consumption and its effects invites less understanding of electricity. Experiments and pilot projects suggest that when consumers obtain obvious price signals (for example, through the use of special meters attached to appliances), they better understand electricity and hence consume it more efficiently.[67] But most people's use of power does not fit into the neat economic models that apply to other forms of consumption.[68]

Survey data confirm the public's generally poor understanding of electricity.[69] In a 2001 study involving roughly 1,500 individuals, researchers found that only 12 percent could correctly answer questions focused on electricity and other energy resources.[70] Despite almost thirty years of energy price shocks and crises, such as the California electricity emergency of 2000–2001, only 36 percent of respondents knew that most U.S. electricity comes from burning oil, coal, and wood; another 36 percent thought that most power came from hydroelectricity, while 16 percent admitted not knowing how electricity was produced.[71]

Into this context of the public's poor understanding of the electric utility infrastructure comes the erection of wind turbines. Unlike the fossil-fuel or nuclear power plants that generate huge amounts of electricity far from population centers, wind turbines have little flexibility regarding their location. But similar to other renewable energy systems like solar photovoltaic cells, wind turbines must be sited where sufficient natural resources exist. Usually, this requirement means that the turbines benefit from placement atop mountains, on Midwestern plains, or offshore, where forceful winds blow consistently. Moreover, beyond their inflexibility of placement, wind turbines produce power in relatively small increments; for example, to obtain the equivalent of a large, though not uncommon, 1,000 MW power plant, a utility would need to generate electricity from more than 300 wind turbines.[72] And because these turbines require spacing between them to

67. Matthew Wiggins, Kurtis McKenney, and James Brodrick, "Residential Energy Monitoring," 88–89.

68. Willett Kempton and Linda L. Layne, "The Consumer's Energy Analysis Environment," 857.

69. For studies of popular knowledge about electricity, see Sam H. Schurr et al., *Energy in America's Future*; Norman Metzger, *Energy*, 181; Robert A. Bernstein and Stephen R. Horn, "Explaining House Voting on Energy Policy"; Gordon Bultena, *Public Response to the Energy Crisis*; and Energy Policy Project of the Ford Foundation, *A Time to Choose*.

70. National Environmental Education & Training Foundation / Roper ASW, *Americans' Low "Energy IQ,"* ii.

71. Ibid., 4. Earlier surveys also found a poor public understanding of energy matters; see Kevin Coyle, *Environmental Literacy in America*, 4.

72. Of course, since wind turbines do not operate 100 percent of the time, 300 3.3-MW turbines do not produce the same amount of energy (in kilowatt-hours) as does a 1,000 MW fossil-fuel or nuclear plant, which operates continuously. The largest commercially available wind turbine in 2012—the Enercon E126—has a rating of about 7.5 MW; more common are turbines having ratings of 2–4 MW, such as the General Electric

avoid the effects of aerodynamic instabilities, they cannot be placed in concentrated fashion like conventional power plants.[73] Hence wind-turbine "farms" sometimes stretch for miles across mountain ridges and fields, with their power contributions shunted to collection centers and then transferred to the grid. Put simply, traditional, large-scale "power is compact and quiet, whereas wind power is expansive and obvious."[74]

In summary, electric power generation and consumption over the past century have lent themselves to visual obscurity and, for the most part, sensory detachment, such that most consumers experience electricity as a strange and incomprehensible commodity. Such detachment essentially means, according to Pasqualetti, that people "had forgotten that there is more to keeping homes supplied with energy than simply paying for it." Expressed even more directly, he notes that "[m]ost of us have not known—or cared—where our electricity comes from."[75] Placing easily visible wind turbines on mountain tops or near shorelines forces electricity production into view and causes "visual and cognitive engagement—an uncomfortable shift that perhaps means more than just NIMBY reactions," according to Borg.[76] Along with other subtle and rarely discussed reasons, such as those that draw on rural–urban animosities, wind turbines generate a substantial amount of opposition, even among those (such as environmental advocates) who realize the potential benefits.

Conclusions

This study of opposition to wind turbines suggests that creation of energy policy, like other policy concerning technology, depends on much more than rational considerations of economics, environmental trade-offs, and equitable land use. While important elements, these factors often draw the most attention of policymakers and those who report on their work, simply because they can be easily understood and, quite often, quantified.

However, people may oppose wind-turbine technology for difficult-to-articulate reasons that draw on their sense of nature and antipathy toward urban businesspeople who seek to exploit resources at the expense of rural residents. Even less quantifiable, opposition arises because the technology forces individuals to ponder, often for the first time, that their electricity-

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4.1-113 turbine. See Enercon, "E126"; and General Electric Company, "4.1-113 Wind Turbine."

73. L. J. Vermeer, J. N. Sørensen, and A. Crespo, "Wind Turbine Wake Aerodynamics"; Johan Meyers and Charles Meneveau, "Optimal Turbine Spacing in Fully Developed Wind Farm Boundary Layers."

74. Pasqualetti, "Wind Power," 32.

75. Pasqualetti, "Morality, Space, and the Power of Wind-Energy Landscapes," 386, 381.

76. Kevin Borg, personal communication with authors, 1 December 2011.

based lifestyles require new sources of energy. Traditional electric generators were usually built in obscure locations, perceptible only to a few people. But wind turbines, by their very nature, require a highly dispersed and visible distribution, often in attractive and unspoiled areas. In short, the public's opinion of energy policy choices sometimes depends on more than logical discussions of quantifiable and expressible considerations.[77]

This interpretation has value for several audiences. For the policy community, our analysis has meaningful implications by directly challenging the traditional means of evaluating opposition to wind energy. Policymakers and energy analysts should, for example, avoid presuming that consumers always make rational decisions. In some cases, stakeholders may first determine their positions based on feelings toward other participants or for other noneconomic reasons. Hence, rural landowners may resentfully consider outside wind-energy developers to be greedy, self-serving city slickers. Alternatively, some wind-turbine opponents may seek to avoid decisions dealing with a technological system with which they have previously had little sensory or mental engagement, partly because of the system's opacity or invisibility.

This invisibility, in turn, hinders acceptance of devices that remain so noticeable, forcing people to think about the electric utility system as a whole and their own roles within it. As Thayer expresses it, "[t]oday we find ourselves in a deeply fragmented situation where we love nature but depend on technology." He observes that people "divide technology into that which feels natural to us (even though we may know of it operationally and intellectually as 'technology' distinct from 'nature') and that which doesn't." By establishing a separation between technologies that have caused trauma to the natural environment and the technologies we use (but have naturalized and think little about), "we maintain the illusion that we as individuals are neither part of nor responsible for the enveloping technological fabric that makes up our contemporary world."[78] Highly visible wind turbines impel people to confront this illusion in a manner that often leads to their opposition to the technology.

This experience with wind-turbine opposition also suggests another policy lesson: no matter how one attempts to accommodate opponents, they will never be mollified. For example, if we understand that some objections

77. Of course, some people who oppose wind turbines (and other technologies) for difficult-to-express reasons will often focus on more "rational" reasons to make their cases to regulatory bodies and others. After all, an environmental agency would respond more favorably to opponents' assertion that endangered species of birds would be killed by wind turbines than to claims that the technology seems "out of place." Pasqualetti observes that opponents of wind projects raise almost any type of objection, such as "threats to the health of marine life and birds, navigational safety, water quality, and infringement on ancient Indian burial sites," as long as "it helps slow or defeat a project" (see "Opposing Wind Energy Landscapes," 910).

78. Thayer, *Gray World, Green Heart*, 94–96.

draw on the historic conflicts between rural and urban values, we would realize that no tinkering with some physical characteristics of the wind turbines (such as their height and distance between them and property lines, known as setbacks), will have much impact on opponents; they will remain indifferent to these accommodations and continue to resist installation of the turbines. On the other hand, a straightforward educational approach may convert opponents who object to the technology because they do not understand the process of generating electricity from fossil fuels and why their lifestyles often lead to increased energy consumption. As a result of this instructional effort, stakeholders may discover that electricity use requires explicit choices, and that wind power, with all its downsides, may be the least bad choice. (The educational experience would also serve as an opportunity to emphasize the value of energy efficiency, which might be considered the best choice because it requires no construction of new generation facilities.)

Our interpretation of opposition to wind turbines offers a more broad-based lesson for energy policymakers. Typically, governments seeking to encourage renewable energy technologies put most of their research-and-development efforts into improving hardware. Funding goes toward augmenting the electricity output of turbines or improvements that enable them to operate better in hostile environments, such as salty, humid, coastal places. But as social science scholars (especially historians of technology) have emphasized for decades, technical success does not always mean commercial or public acceptance. Wind turbines have steadily improved since the 1980s, producing more power at lower costs; yet, for both obvious and subtle reasons, the devices still raise serious objections when promoters choose specific sites. It might, therefore, be wise to spend some research money on better understanding the social, cultural, and behavioral reasons for wind-power opposition, and for educating the public about the operation of the electric utility system.

In addition, our study confirms the benefit of historical analysis by exposing the contingent and political nature of existing energy configurations. In other words, this essay uses historical research to broaden the scope of energy policy discussions by highlighting overlooked considerations and by illuminating the behavior and goals of various stakeholders.[79] Examples from the history of wind turbines show that electric-power policy remains a site of conflict, one encompassing matrices of different values and ideologies that often remain unappreciated by the policy community. At the same time, this research demonstrates that historians can use their craft constructively to render concealed technologies visible through their discussions of how the public perceives hardware and infrastructures within the natural environment. They can explain, as here we have attempted to do, the meanings given to the space in which people live based

79. Richard F. Hirsh, "Historians of Technology in the Real World," 8.

on different representations of progress, modernity, and the natural world. By comprehending the history of a given energy source and describing its entry into the social and historical consciousness, scholars can help others understand why certain technologies occasionally encounter challenges that ostensibly seem to make no logical sense. By doing so, academics can validate Supreme Court Justice Oliver Wendell Holmes Jr.'s claim that "a page of history is worth a volume of logic."[80]

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