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Committee on ... Commerce, Utilities and Rail (SC-CUR)

COMMITTEE NOTICES ...

- *Committee Reports* ... CR
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INFORMATION COLLECTED BY COMMITTEE FOR AND AGAINST PROPOSAL

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• Visual clutter often is adversely perceived and commonly results from the combination of human-made elements in close association that are of differing shapes, colors, forms, patterns, or scales. Generally simple and uniform arrays or groupings of wind turbines are more visually appealing than mixed types and sizes. Screening of associated infrastructure also is important in reducing visual clutter.

• Turbines with rotating blades have been shown to be more visually appealing than those that are still. Maintenance or removal of poorly functioning turbines can be important.

• Turbine noise usually is most critical within a half-mile of a project. Efforts to reduce potential noise impacts on nearby residents therefore may be most important within that distance.

• Decommissioning wind-energy projects appropriately would be considered in initial permit approvals. While some wind-energy projects may have longer life spans than originally anticipated, provisions are needed for removal of site structures that no longer contribute to the project, and for site restoration. Funding provided in escrow for decommissioning is sometimes essential.

• Obstruction lighting required on objects more than 200 feet tall often is an extremely important aesthetic concern. Eliminating or reducing major lighting impacts merits a high priority.

CULTURAL IMPACTS

Recreation

Wind-energy facilities create both positive and negative recreational impacts. On the positive side, many wind-energy projects are listed as tourist sights: some offer tours or provide information areas about the facility and wind energy in general; and several are considering incorporating visitor centers. Some developers allow open access to project sites that may provide additional opportunities for hunting, hiking, snowmobiling, and other activities.

There are two types of potential negative impacts on recreational opportunities: direct and indirect. Direct impacts can result when existing recreational activities are either precluded or require rerouting around a wind-energy facility. Indirect impacts include aesthetic impacts (addressed above) that may affect the recreational experience. These impacts can occur when scenic or natural values are critical to the recreational experience.

Most wind projects to date have been located on or proposed for private land. Policies vary regarding public use around wind turbines on both private and public lands. At project sites, access roads are often gated to count in their bodies, especially their chests, the beats of the blades passing the towers, even when they can't hear or see them." More needs to be understood regarding the effects of low-frequency noise on humans.

Assessment

Guidelines for measuring noise produced by wind turbines are provided in the standard, IEC 61400-11: Acoustic Noise Measurement Techniques for Wind Turbines (IEC 2002), which specifies the instrumentation, methods, and locations for noise measurements. Wind-energy developers are required to meet local standards for acceptable sound levels; for example, in Germany, this level is 35 dB(A) for rural nighttime environments. Noise levels in the vicinity of wind-energy projects can be estimated during the design phase using available computational models (DWEA 2003a). Generally, noise levels are only computed at low wind speeds (7-8 m/s), because at higher speeds, noise produced by turbines can be (but is not always) masked by ambient noise.

Noise-emission measurements potentially are subject to problems, however. A 1999 study involving noise-measurement laboratories from seven European countries found, in measuring noise emission from the same 500 kW wind turbine on a flat terrain, that while apparent sound power levels and wind speed dependence could be measured reasonably reliably, tonality measurements were much more variable (Kragh et al. 1999). In addition, methods for assessing noise levels produced by wind turbines located in various terrains, such as mountainous regions, need further development.

Mitigation Measures and Standards

Noise produced by wind turbines generally is not a major concern for humans beyond a half-mile or so because various measures to reduce noise have been implemented in the design of modern turbines. The mechanical sound emanating from rotating machinery can be controlled by sound-isolating techniques. Furthermore, different types of wind turbines have different noise characteristics. As mentioned earlier, modern upwind turbines are less noisy than downwind turbines. Variable-speed turbines (where rotor speeds are lower at low wind speeds) create less noise at lower wind speeds when ambient noise is also low, compared with constant-speed turbines. Direct-drive machines, which have no gearbox or high-speed mechanical components, are much quieter.

Acceptability standards for noise vary by nation, state, and locality. They can also vary depending on time of day—nighttime standards are generally stricter. In the United States, the U.S. Environmental Protection Agency only provides noise guidelines. Many state governments issue their own regulations (e.g., Oregon Department of Environmental Quality

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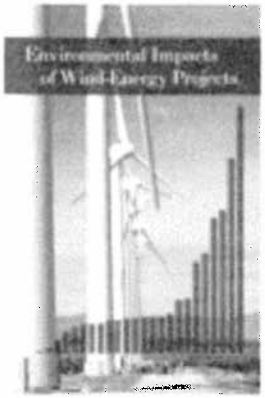

Environmental Impacts of Wind-Energy Projects

Committee on Environmental Impacts of Wind Energy Projects, National Research Council

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There has been rapid growth in the construction of wind-powered electricity generating facilities over the past 25 years in the United States. Wind-energy facilities emit no atmospheric pollutants and are driven by a renewable source, addressing multiple environmental concerns such as air quality and climate change. But the expansion of such facilities can carry adverse environmental impacts. As wind energy development continues to expand, federal, state and local agencies should adopt a coordinated approach to evaluating the planning, regulation, and location of wind-energy projects. This National Research Council report provides a framework that can help in evaluating tradeoffs between the benefits of new wind-energy projects and risks of adverse environmental impacts before projects begin.

Contents

Summary

INTRODUCTION

In recent years, the growth of capacity to generate electricity from wind energy has been rapid, growing from almost none in 1980 to 11,603 megawatts (MW) in 2006 in the United States and about 60,000 MW in 2006 globally. Despite this rapid growth, wind energy amounted to less than 1% of U.S. electricity generation in 2006.

Generation of electricity by wind energy has the potential to reduce environmental impacts caused by use of fossil fuels to generate electricity because, unlike fossil fuels, wind energy does not generate atmospheric contaminants or thermal pollution, thus being attractive to many governments, organizations, and individuals. Others have focused on adverse environmental impacts of wind-energy facilities, which include aesthetic and other impacts on humans and effects on ecosystems, including the killing of wildlife, especially birds and bats. Some environmental effects of wind-energy facilities, especially those from transportation (roads to and from the plant site) and transmission (roads or clearings for transmission lines), are common to all electricity-generating plants; other effects, such as their aesthetic impacts, are specific to wind-energy facilities.

This report provides analyses to help to understand and evaluate positive and negative environmental effects of wind-energy facilities. The committee was not asked to consider, and therefore did not address, non-environmental issues associated with generating electricity from wind energy, such as energy independence, foreign-policy considerations, resource utilization, and the balance of international trade.

Wind energy has a long history, having been used for sailing vessels at least since 3100 BC. Traditionally, windmills were used to lift water and grind grain as early as the 10th century AD. However, significant electricity generation from wind in the United States began only in the 1980s, in California; today, electricity is generated from wind in 36 states, including Alaska and Hawaii.

There has been a rapid evolution of wind-turbine design over the past 25 years. Thus, modern turbines are different in many ways from the turbines that were originally installed in California's three large installations at Altamont Pass, Tehachapi, and San Gorgonio (Palm Springs). A typical modern generator consists of a pylon about 60 to 90 meters (m) high with a three-bladed rotor about 70 to 90 m in diameter mounted atop it. Larger blades and taller towers are becoming more common. Other support facilities usually include relatively small individual buildings and a substation.

This study is concerned with utility-scale clusters of generators often referred to as "wind farms," not with small turbines used for individual agricultural farms or houses. Some of the installations contain hundreds of turbines; the wind installation at Altamont Pass in California consists of more than 5,000, and those at Tehachapi and Palm Springs contain at least 3,000 each, ranging from older machines as small as 100 kilowatts (kW) to more modern 1.5 MW turbines. The committee that produced this report focused only on installations onshore. There were no offshore wind-energy installations in the United States as of the beginning of 2007.

THE PRESENT STUDY

Statement of Task

The National Research Council was asked to establish an expert committee to carry out a scientific study of the environmental impacts of wind-energy projects, focusing on the Mid-Atlantic Highlands[1] (MAH) as a case example. The study was to consider adverse and beneficial effects, including impacts on landscapes, viewsheds, wildlife, habitats, water resources, air pollution, greenhouse gases, materials-acquisition costs, and other impacts. Using information from wind-energy projects proposed or in place in the MAH and other regions as appropriate, the committee was charged to develop an analytical framework for evaluating those effects to inform siting decisions for wind-energy projects. The study also was to identify major areas of research and development needed to better understand the

[1]The MAH refers to elevated regions of Virginia, West Virginia, Maryland, and Pennsylvania.

environmental impacts of wind-energy projects and to reduce or mitigate negative environmental effects.

Current Guidance for Reviewing Wind-Energy Proposals

The United States is in the early stages of learning how to plan for and regulate wind-energy facilities. Federal regulation of wind-energy facilities is minimal if the facility does not have a federal nexus (that is, receive federal funding or require a federal permit), which is the case for most energy development in the United States. The Federal Energy Regulatory Commission regulates the interstate transmission of electricity, oil, and natural gas, but it does not regulate the construction of individual electricity-generation (except for nonfederal hydropower), transmission, or distribution facilities. Apart from Federal Aviation Administration guidelines, federal and state environmental laws protecting birds and bats are the main legal constraints on wind-energy facilities not on federal lands or without a federal nexus.

Wind energy is a recent addition to the energy mix in most areas, and regulation of wind energy is evolving rapidly. In evaluating current regulatory review processes, the committee was struck by the minimal guidance offered to developers, regulators, or the public about (1) the quantity and kinds of information to be provided for review; (2) the degrees of adverse or beneficial effects of proposed wind developments to consider critical for approving or disallowing a proposed project; and (3) the competing costs and benefits of a proposed project to weigh, and how to weigh them, with regard to that single proposal or in comparison with likely alternatives if that project is not built. Such guidance, and technical assistance with gathering and interpreting information needed for decision making, would be enormously useful. This guidance and technical assistance cast at the appropriate jurisdictional level could be developed by state and local governments working with groups composed of wind-energy developers and nongovernmental organizations representing all views of wind energy, in addition to other government agencies. The matrix of government responsibilities and the evaluation guide in Chapter 5 of this report should help the formulation of such guidance.

The committee judges that material in Chapter 5 could be a major step in the direction of an analytic framework for reviewing wind-energy proposals and for evaluating existing installations. If it were followed and adequately documented, it would provide a basis not only for evaluating an individual project but also for comparing two or more proposed projects and for undertaking an assessment of the cumulative effects of other human activities. It also could be used to project the likely cumulative effects of additional wind-energy facilities whose number and placement are identified in various projections. Finally, following this material would allow for a rational documentation of the most important areas for research.

Environmental Benefits of Wind Energy

The environmental benefits of wind energy accrue through its displacement of electricity generation that uses other energy sources, thereby displacing the adverse environmental effects of those generators. Because the use of wind energy has some adverse impacts, the conclusion that a wind-energy installation has net environmental benefits requires the conclusion that all of its adverse effects are less than the adverse effects of the generation that it displaces. However, this committee's charge was to focus on the use of wind energy; it was not able to evaluate fully the effects of other energy sources. The committee also did not fully evaluate so-called life-cycle effects, those effects caused by the development, manufacture, resource extraction, and other activities affiliated with all energy sources. Thus, in assessing environmental benefits of wind-energy generation of electricity, the committee focused on the degree to which it displaces or renders unnecessary the electricity generated by other sources, and hence on the degree to which it displaces or reduces atmospheric emissions, which include greenhouse gases, mainly carbon dioxide (CO_2); oxides of nitrogen (NO_x); sulfur dioxide (SO_2); and particulate matter. This focus on benefits accruing through reduction of atmospheric emissions, especially of greenhouse-gas emissions, was adopted because those emissions are well characterized and the information is readily available. It also was adopted because much of the public discourse about the environmental benefits of wind energy focuses on its reduction of atmospheric emissions, especially greenhouse-gas emissions. The restricted focus on benefits accruing through reduction of atmospheric emissions also was adopted because the relationships between air emissions and the amount of electricity generated by specified types of electricity-generating sources are well known. However, relationships between incremental changes in electricity generation and other environmental impacts, such as those on wildlife, viewsheds, or landscapes, generally are not known and are unlikely to be proportional. In addition, wind-powered generators of electricity share some kinds of adverse environmental impacts with other types of electricity generators (for example, some clearing of vegetation is required to construct either a wind-energy or a coal-fired power plant and its access roads and transmission lines). Therefore, calculating the extent to which wind energy displaces other sources of electricity generation does not provide clear information on how much, or even whether, those other environmental impacts will be reduced. This report does, however, provide a guide to the methods and information needed to conduct a more comprehensive analysis.

Projections for future wind-energy development, and hence projections for future wind-energy contributions to reduction of air-pollutant emissions in the United States, are highly uncertain. Recent model projections by the U.S. Department of Energy (DOE) for U.S. onshore installed wind-energy capacity in the next 15 years range from 19 to 72 gigawatts, or 2 to 7% of projected U.S. onshore installed electricity-generation capacity. In the same period, wind-energy development is projected to account for 3.5 to 19% of the *increase* in total electricity-generation capacity. If the average wind-turbine size is assumed to be 2 MW (larger than most current turbines), 9,500 to 36,000 wind turbines would be needed to achieve that projected capacity.

Because the wind blows intermittently, wind turbines often produce less electricity than their rated maximum output. On average in the mid-Atlantic region, the capacity factor of turbines—the fraction of their rated maximum output that they produce on average—is about 30% for current technology, and is forecast to improve to nearly 37% by the year 2020. Those are the fractions the committee used in estimating how much wind energy would displace other sources. Other factors, such as how wind energy is integrated into the electrical grid and how quickly other energy sources can be turned on and off, also affect the degree to which wind displaces other energy sources and their emissions. Those other factors probably further reduce the 30% (or projected 37%) figure, but the reduction probably is small, at least for the projected amount of onshore wind development in the United States. The net result in the mid-Atlantic region is unclear. Because the amount of atmospheric pollutants emitted varies from one energy source to another, assumptions must be made about which energy source will be displaced by wind. However, even assuming that all the electricity generation displaced by wind in the mid-Atlantic region is from coal-fired power plants, as one analysis has done, the results do not vary dramatically from those based on the assumption that the average mix of electricity sources in the region is displaced.

In addition to CO_2, coal-fired power plants also are important sources of SO_2 and NO_x emissions. Those two pollutants cause acid deposition and contribute to concentrations of airborne particulate matter. NO_x is an important precursor to ozone pollution in the lower atmosphere. However, because current and upcoming regulatory controls on emissions of NO_x and SO_2 from electricity generation in the eastern United States involve total caps on emissions, the committee concludes that development of wind-powered electricity generation using current technology probably will not result in a significant reduction in total emission of these pollutants from the electricity sector in the mid-Atlantic region.

Conclusions

- Using the future projections of installed U.S. energy capacity by the DOE described above, the committee estimates that wind-energy development probably will contribute to offsets of approximately 4.5% in U.S. emissions of CO_2 from electricity generation by other electricity-generation sources by the year 2020. In 2005, electricity generation produced 39% of all CO_2 emissions in the United States.
- Wind energy will contribute proportionately less to electricity generation in the mid-Atlantic region than in the United States as a whole, because a smaller portion of the region has high-quality[2] wind resources than the portion of high-quality wind resources in the United States as a whole.
- Electricity generated in the MAH—including wind energy—is used in a regional grid in the larger mid-Atlantic region. Electricity generated from wind energy in the MAH has the potential to displace pollutant emissions, discharges, wastes, and other adverse environmental effects of other sources of electricity generation in the grid. That potential is estimated to be less than 4.5%, and the degree to which its beneficial effects would be realized in the MAH is uncertain.
- If the future were to bring more aggressive renewable-energy-development policies, potential increased energy conservation, and improved technology of wind-energy generation and transmission of electricity, the contribution of wind energy to total electricity production would be greater. This would affect our analysis, including projections for development and associated effects (for example, energy supply, air pollution, and development footprint). On the other hand, if technological advances serve to reduce the emissions and other negative effects of other sources of electricity generation or if fossil-fuel prices fall, the committee's findings might overestimate wind's contribution to electricity production and air-pollution offsets.
- Electricity generated from different sources is largely fungible. Depending on factors such as price, availability, predictability, regulatory and incentive regimes, and local considerations, one source might be preferentially used over others. The importance of the factors changes over varying time scales. As a result, a more complete understanding of the environmental and economic effects of any one energy source depends on a more complete understanding of how that energy source displaces or is displaced by other energy sources, and it depends on a more complete understanding of the environmental and economic effects of all other available

[2]The quality of a wind resource refers to the amount of wind available for wind-powered generation of electricity.

energy sources. Developing such an understanding would have great value in helping the United States make better-informed choices about energy sources, but that was beyond this committee's charge. Nonetheless, the analyses in this report have value until such time as a more comprehensive understanding is developed.

Ecological Impacts

Wind turbines cause fatalities of birds and bats through collision, most likely with the turbine blades. Species differ in their vulnerability to collision, in the likelihood that fatalities will have large-scale cumulative impacts on biotic communities, and in the extent to which their fatalities are discovered. Probabilities of fatality are a function of both abundance and behavioral characteristics of species. Among bird species, nocturnal, migrating passerines[3] are the most common fatalities at wind-energy facilities, probably due to their abundance, although numerous raptor fatalities have been reported, and raptors may be most vulnerable, particularly in the western United States. Among bats, migratory tree-roosting species appear to be the most susceptible. However, the number of fatalities must be considered in relation to the characteristics of the species. For example, fatalities probably have greater detrimental effects on bat and raptor populations than on most bird populations because of the characteristically long life spans and low reproductive rates of bats and raptors and because of the relatively low abundance of raptors.

The type of turbines may influence bird and bat fatalities. Newer, larger turbines appear to cause fewer raptor fatalities than smaller turbines common at the older wind-energy facilities in California, although this observation needs further comparative study to better account for such factors as site-specific differences in raptor abundance and behavior. However, the data are inadequate to assess relative risk to passerines and other small birds. It is possible that as turbines become larger and reach higher, the risk to the more abundant bats and nocturnally migrating passerines at these altitudes will increase. Determining the effect of turbine size on avian risk will require more data from direct comparison of fatalities from a range of turbine types.

The location of turbines within a region or landscape influences fatalities. Turbines placed on ridges, as many are in the MAH, appear to have a higher probability of causing bat fatalities than those at many other sites.

The overall importance of turbine-related deaths for bird populations is unclear. Collisions with wind turbines represent one element of the cumu-

[3]Passerines are small to medium mainly perching songbirds; about half of all U.S. birds are passerines.

lative anthropogenic impacts on these populations; other impacts include collisions with other structures and vehicles, and other sources of mortality. As discussed in Chapter 3, those other sources kill many more birds than wind turbines, even though precise data on total bird deaths caused by most of these anthropogenic sources are sparser and less reliable than one would wish. Chapter 3 also makes clear that any assessment of the importance of a source of bird mortality requires information and understanding about the species affected and the likely consequences for local populations of those species.

The construction and maintenance of wind-energy facilities also alter ecosystem structure through vegetation clearing, soil disruption and potential for erosion, and noise. Alteration of vegetation, including forest clearing, represents perhaps the most significant potential change through fragmentation and loss of habitat for some species. Such alteration of vegetation is particularly important for forest-dependent species in the MAH. Changes in forest structure and the creation of openings alter microclimate and increase the amount of forest edge. Plants and animals throughout an ecosystem respond differently to these changes. There might also be important interactions between habitat alteration and the risk of fatalities, such as bat foraging behavior near turbines.

Conclusions

- Although the analysis of cumulative effects of anthropogenic energy sources other than wind was beyond the scope of the committee, a better analysis of the cumulative effects of various anthropogenic energy sources, including wind turbines, on bird and bat fatalities is needed, especially given projections of substantial increases in the numbers of wind turbines in coming decades.
- In the MAH, preliminary information indicates that more bats are killed than was expected based on experience with bats in other regions. Not enough information is available to form a reliable judgment on whether the number of bats being killed will have overall effects on populations, but given a general region-wide decline in the populations of several species of bats in the eastern United States, the possibility of population effects, especially with increased numbers of turbines, is significant.
- At the current level of wind-energy development (approximately 11,600 MW of installed capacity in the United States at the end of 2006, including the older California turbines), the committee sees no evidence that fatalities caused by wind turbines result in measurable demographic changes to bird populations in the United States, with the possible exception of raptor fatalities in the Altamont Pass area, although data are lacking for a substantial portion of the operating facilities.

- There is insufficient information available at present to form a reliable judgment on the likely effect of all the proposed or planned wind-energy installations in the mid-Atlantic region on bird and bat populations. To make such a judgment, information would be needed on the future number, size, and placement of those turbines; more information on bird and bat populations, movements, and susceptibility to collisions with turbines would be needed as well. Lack of replication of studies among facilities and across years makes it impossible to evaluate natural variability.

Recommendation

- Standardized studies should be conducted before siting and construction and after construction of wind-energy facilities to evaluate the potential and realized ecological impacts of wind development. Pre-siting studies should evaluate the potential for impacts to occur and the possible cumulative impacts in the context of other sites being developed or proposed. Likely impacts could be evaluated relative to other potentially developable sites or from an absolute perspective. In addition, the studies should evaluate a selected site to determine whether alternative facility designs would reduce potential environmental impacts. Post-construction studies should focus on evaluating impacts, actual versus predicted risk, causal mechanisms of impact, and potential mitigation measures to reduce risk and reclamation of disturbed sites. Additional research is needed to help assess the immediate and long-term impacts of wind-energy facilities on threatened, endangered, and other species at risk. Details of these recommendations, including the frequency and duration of recommended pre-siting, pre-construction, and post-construction studies and the need for replication, are in Chapter 3.

Impacts on Humans

The human impacts considered by the committee include aesthetic impacts; impacts on cultural resources, such as historic, sacred, archeological, and recreation sites; impacts on human health and well-being, specifically from noise and from shadow flicker; economic and fiscal impacts; and the potential for electromagnetic interference with television and radio broadcasting, cellular phones, and radar. This is not an exhaustive list of all possible human impacts from wind-energy projects. For example, the committee did not address potentially significant social impacts on community cohesion, such as cases where proposed wind-energy facilities might cause rifts between those who favor them and those who oppose them. Psychological impacts—positive as well as negative—that can arise in confronting a controversial project also were not addressed.

There has been relatively little dispassionate analysis of the human impacts of wind-energy projects in the United States. In the absence of extensive data, this report focuses mainly on appropriate methods for analysis and assessment and on recommended practices in the face of uncertainty. Chapter 4 contains detailed conclusions and recommendations concerning human impacts, including guides to best practices and descriptions of information needs. General conclusions and recommendations concerning human impacts follow.

Conclusions

- There are systematic and well-established methods for assessing and evaluating human impacts (described in Chapter 4); they allow better-informed and more-enlightened decision making.
- Although aesthetic concerns often are the most-vocalized concerns about proposed wind-energy projects, few decision processes adequately address them. Although methods for assessing aesthetic impacts need to be adapted to the particular characteristics of wind-energy projects, such as their visibility, the basic principles (described in Chapter 4 and Appendix D) of systematically understanding the relationship of a project to surrounding scenic resources apply and can be used to inform siting and regulatory decisions.

Recommendations

- Because relatively little research has been done on the human impacts of wind-energy projects, when wind-energy projects are undertaken, routine documentation should be made of processes that allow for local interactions concerning the impacts that arise during the lifetime of the project, from proposal through decommissioning, as well as processes for addressing the impacts themselves. Such documentation will facilitate future research and therefore improve future siting decisions.
- Human impacts should be considered within the context of the environmental impacts discussed in Chapter 3 and the broader contextual analysis of wind energy—including its electricity-production benefits and limitations—presented in Chapter 2. Moreover, the conclusions and recommendations concerning human impacts presented by topic in Chapter 4 should not be considered in isolation; instead, they should be treated as part of a process. Questions and issues concerning human impacts should be covered in assessments and regulatory reviews of wind-energy projects.

Analyzing Adverse and Beneficial Impacts in Context

The committee's charge included the development of an analytical framework for evaluating environmental and socioeconomic effects of wind-energy developments. As described in Chapter 1, an ideal framework that addressed all effects of wind energy across a variety of spatial and temporal scales would require more information than the committee could gather, given its time and resources, and probably more information than currently exists. In addition, energy development in general, and wind-energy development in particular, are not evaluated and regulated in a comprehensive and comparative way in the United States, and planning for new energy resources also is not conducted in this manner. Instead, planning, regulation, and review usually are done on a project-by-project basis and on local or regional, but not national, scales. In addition, there are few opportunities for full life-cycle analyses or consideration of cumulative effects.

There also are no agreed-on standards for weighting of positive and negative effects of a proposed energy project and for comparing those effects to those of other possible or existing projects. Indeed, the appropriate standards and methods of conducting such comparisons are not obvious, and it is not obvious what the appropriate space and times scales for the comparisons should be. Therefore, a full comparative analysis has not been attempted here.

The committee approached its task—to carry out a scientific study of the adverse and beneficial environmental effects of wind-energy projects—by analyzing the information available and identifying major knowledge gaps. Some of the committee's work was made difficult by a lack of information and by a lack of consistent (or even any) policy guidance at local, state, regional, or national levels about the importance of various factors that need to be considered. In particular, the committee describes in Chapter 1 and Chapter 5 the reasons that led us to stop short of providing a full analytic framework and instead to offer an evaluation guide to aid coordination of regulatory review across levels of government and across spatial scales and to help to ensure that regulatory reviews are comprehensive in addressing the many facets of the human and nonhuman environment that can be affected by wind-energy development.

Framework for Reviewing Wind-Energy Proposals

Conclusion

- A country as large and as geographically diverse as the United States and as wedded to political plurality and private enterprise is unlikely to plan for wind energy at a national scale in the same way as some European countries are doing. Nevertheless, national-level energy policies (implemented through such mechanisms as incentives, subsidies, research agendas, and federal regulations and guidelines) to enhance the benefits of wind energy while minimizing the negative impacts would help in planning and regulating wind-energy development at smaller scales. Uncertainty about what policy tools will be in force hampers proactive planning for wind-energy development. More-specific conclusions and recommendations follow.

Conclusion

- Because wind energy is new to many state and local governments, the quality of processes for permitting wind-energy developments is uneven in many respects.

Recommendation

- Guidance on planning for wind-energy development, including information requirements and procedures for reviewing wind-energy proposals, as outlined in Chapter 5, should be developed. In addition, technical assistance with gathering and interpreting information needed for decision making should be provided. This guidance and technical assistance, conducted at appropriate jurisdictional levels, could be developed by working groups composed of wind-energy developers; nongovernmental organizations with diverse views of wind-energy development; and local, state, and federal government agencies.

Conclusion

- There is little anticipatory planning for wind-energy projects, and even if it occurred, it is not clear whether mechanisms exist that could incorporate such planning in regulatory decisions.

Recommendation

- Regulatory reviews of individual wind-energy projects should be preceded by coordinated, anticipatory planning whenever possible. Such planning for wind-energy development, coordinated with regulatory review of wind-energy proposals, would benefit developers, regulators, and the public because it would prompt developers to focus proposals on locations and site designs most likely to be successful. This planning could be implemented at scales ranging from state and regional levels to local levels. Anticipatory planning for wind-energy development also would help researchers to target their efforts where they will be most informative for future wind-development decisions.

Conclusion

- Choosing the level of regulatory authority for reviewing wind-energy proposals carries corresponding implications for how the following issues are addressed:

(1) cumulative effects of wind-energy development;
(2) balancing negative and positive environmental and socioeconomic impacts of wind energy; and
(3) incorporating public opinions into the review process.

Recommendation

- In choosing the levels of regulatory review of wind-energy projects, agencies should review the implication of those choices for all three issues listed above. Decisions about the level of regulatory review should include procedures for ameliorating the disadvantages of a particular choice (for example, enhancing opportunities for local participation in state-level reviews).

Conclusion

- Well-specified, formal procedures for regulatory review enhance predictability, consistency, and accountability for all parties to wind-energy development. However, flexibility and informality also have advantages, such as matching the time and effort expended on review to the complexity and controversy associated with a particular proposal; tailoring decision criteria to the ecological and social contexts of a particular proposal; and fostering creative interactions among developers, regulators, and the public to find solutions to wind-energy dilemmas.

Recommendation

- When consideration is given to formalizing review procedures and specifying thresholds for decision criteria, this consideration should include attention to ways of retaining the advantages of more flexible procedures.

Conclusion

- Using an evaluation guide such as the one recommended in Chapter 5 to organize regulatory review processes can help to achieve comprehensive and consistent regulation coordinated across jurisdictional levels and across types of effects.

Recommendation

- Regulatory agencies should adopt and routinely use an evaluation guide in their reviews of wind-energy projects. The guide should be available to developers and the public.

Conclusion

- The environmental benefits of wind-energy development, mainly reductions in atmospheric pollutants, are enjoyed at wide spatial scales, while the environmental costs, mainly aesthetic impacts and ecological impacts, such as increased mortality of birds and bats, occur at much smaller spatial scales. There are similar, if less dramatic, disparities in the scales of realized economic and other societal benefits and costs. The disparities in scale, although not unique to wind-energy development, complicate the evaluation of tradeoffs.

Recommendation

- Representatives of federal, state, and local governments should work with wind-energy developers, nongovernmental organizations, and other interest groups and experts to develop guidelines for addressing tradeoffs between benefits and costs of wind-energy generation of electricity that occur at widely different scales, including life-cycle effects.

Environmental Impacts of Wind-Energy Projects

Committee on Environmental Impacts of Wind-Energy Projects

Board on Environmental Studies and Toxicology

Division on Earth and Life Studies

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Preface

The generation of electricity from wind energy is surprisingly controversial. At first glance, obtaining electricity from a free source of energy—the wind—seems to be an optimum contribution to the nation's goal of energy independence and to solving the problem of climate warming due to greenhouse gas emissions. As with many first glances, however, a deeper inspection results in a more complicated story. How wind turbines are viewed depends to some degree on the environment and people's predilections, but not everyone considers them beautiful. Building wind-energy installations with large numbers of turbines can disrupt landscapes and habitats, and the rotating turbine blades sometimes kill birds and bats. Calculating how much wind energy currently displaces other, presumably less-desirable, energy sources is complicated, and predicting future displacements is surrounded by uncertainties.

Although the use of wind energy has grown rapidly in the past 25 years, frequently subsidized by governments at various levels and in many countries eager to promote cleaner alternative energy sources, regulatory systems and planning processes for these projects are relatively immature in the United States. At the national scale, regulation is minimal, unless the project receives federal funding, and the regulations are generic for construction and management projects or are promulgated as guidelines. Regulation at the state and local level is variable among jurisdictions, some with well-developed policies and others with little or no framework, relying on local zoning ordinances. There are virtually no policy or regulatory frameworks at the multistate regional scale, although of course the impacts and benefits of wind-energy installations are not constrained by political boundaries.

This is the complex scientific and policy environment in which the committee worked to address its responsibility to study the environmental impacts of wind energy, including the adverse and beneficial effects. Among the specified considerations were the impacts on landscapes, viewsheds, wildlife, habitats, water resources, air pollution, greenhouse gases, materials-acquisition costs, and other impacts. The committee drew on information from throughout the United States and abroad, but by its charge, focused on the Mid-Atlantic Highlands (a mountainous region in Pennsylvania, Virginia, Maryland, and West Virginia). Using existing information, the committee was able to develop a framework for evaluating those effects; we hope this framework can inform future siting decisions of wind-energy projects. Often, there is insufficient information to provide certainty for these decisions, and thus in the process of its work the committee identified major research needed to improve the assessment of impacts and inform the siting and operational decisions of wind-energy projects.

The committee membership included diverse areas of expertise needed to address the committee's charge. Committee members originated from across the United States, and one hails from Denmark, adding to the international perspective of the study. Members represented the public and private sectors, and numerous natural and social science disciplines. But most important, the committee worked together as a cohesive group in deciding what issues were important and how important, examining issues from multiple perspectives, recognizing and dealing with biases, framing questions and issues in formats that would convey information effectively to decision makers, and considering, respecting, and reconciling differences of opinion, judgment, and interpretation.

The committee broadly defined "environmental" impacts to include traditional environmental measures such as species, habitats, and air and water quality, but attention was also devoted to aesthetic, cultural, recreational, social, and economic impacts. The committee recognized that the planning, policy, and regulatory considerations were paramount if information about impacts was to be translated into informed decision making. Finally, because decision making about wind-energy projects occurs at a variety of geographic and jurisdictional levels, the committee paid careful attention to scale issues as it addressed impacts and benefits.

The benefits of wind energy depend on the degree to which the adverse effects of other energy sources can be reduced by using wind energy instead of the other sources. Assessing those benefits is complicated. The generation of electricity by wind energy can itself have adverse effects, and projecting the amount of wind-generated electricity available in the future is quite uncertain. In addition, the amount of potential displacement of other energy sources depends on characteristics of the energy market, operation of the transmission grid, capacity factor of the wind-energy generators as well as that of other types of electricity generators, and regulatory policies and practices affecting the production of greenhouse gases. Even if the amount of energy that wind energy displaces is small, it is clear that the nation will depend on multiple energy sources for the foreseeable future and reduction of environmental impacts will thereby require multiple approaches.

The committee began its work expecting that there would be measurable environmental impacts, including biological and socioeconomic impacts, and that there would be inadequate data from which to issue definitive, broadly applicable determinations. Given the complexity of the electric-power industry, the dynamics of energy markets, and the rapidity of technological change, we also expected that predicting the environmental benefits of wind energy would be challenging. On the other hand, the lack of any truly coordinated planning, policy, and regulatory framework at all jurisdictional levels loomed larger than expected throughout our deliberations. Although some predictions about future adverse environmental effects of wind-energy use can be made, the committee recognized gaps in our knowledge and recommended specific monitoring studies that will enable more rigorous siting and operational decisions in the future. Similarly, the report includes descriptions of measures of social impacts of wind-energy development, and recommends studies that would improve our understanding of these impacts.

The complexity of assessing the environmental impacts of wind-energy development can be organized in a three-dimensional action space. These dimensional axes include spatial jurisdictions (local, state/regional, and federal), timing of project stages (pre-project, construction, operational, and post-operational) and environmental and human impacts, each of which include their own time and space considerations. The committee evaluated these issues in offering an evaluation guide for organizing the assessment of environmental impacts. We hope that the results of these deliberations and the evaluations and observations in this report will significantly improve the nation's ability to plan, regulate, and assess the impacts of wind-energy development.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their review of this report:

Jan Beyea, Consulting in the Public Interest
Dallas Burtraw, Resources for the Future
Michael Corradini, University of Wisconsin-Madison
Samuel Enfield, PPM Atlantic Renewable
Chris Hendrickson, Carnegie Mellon University
Alan Hicks, New York Department of Environmental Conservation
Mark Jacobson, Stanford University
Kevin Porter, Exeter Associates
Paul Kerlinger, Curry & Kerlinger, LLC
Ronald Larkin, Illinois Natural History Survey
Martin Pasqualetti, Arizona State University
John Sherwell, Maryland Department of Natural Resources
Linda Spiegel, California Energy Commission
James Walker, enXco, Inc.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by the review coordinator, Gordon H. Orians of the University of Washington (emeritus), and the review monitor, Elsa M. Garmire of Dartmouth College. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

The committee gratefully acknowledges the following for making presentations to the committee: Dick Anderson (WEST, Inc.), Edward Arnett (Bat Conservation International), Dinah Bear (Council on Environmental Quality), Gwenda Brewer (Maryland Department of Natural Resources), Daniel Boone (Consultant), Steve Brown (West Virginia Department of Natural Resources), Richard Cowart (The Regulatory Assistance Project), Samuel Enfield (PPM Atlantic Renewable), Ken Hamilton (Whitewater Energy), Alex Hoar (U.S. Fish and Wildlife Service), Judith Holyoke Schoyer Rodd (Friends of the Blackwater), Tom Kerr (U.S. Environmental Protection Agency), Julia Levin (California Audubon), Patricia McClure (Government Accountability Office), The Honorable Alan B. Mollohan (U.S. Representative, WV 1st Congressional District), Kevin Rackstraw (American Wind Energy Association Siting Committee), Dennis Scullion (EnXco, Inc.), John Sherwell (Maryland Department of Natural Resources), Craig Stihler (West Virginia Department of Natural Resources), Robert Thresher (National Renewable Energy Laboratory), James A. Walker (EnXco, Inc.), and Carl Zichella (Sierra Club). In addition, John Reynolds and Joseph Kerecman of PJM Interconnection and officials of Dominion Resources provided helpful information to the committee through personal communications; Laurie Jodziewicz of the American Wind Energy Association, Nancy Rader of the California Wind Energy Association, and Linda White of the Kern Wind Energy Association provided helpful information and contacts. We also thank Wayne Barwikowski and his colleagues at enXco, Inc. for their informative and helpful tour of the San Gorgonio (Palm Springs) wind-energy facility.

The committee's work was enhanced in every way by the extraordinary work of the project director, David Policansky, who provided endless sound advice, insightful expertise, and just good sense. The committee offers David its sincere gratitude for his attentive assistance and for his good fellowship throughout the project, which involved five meetings in five different locations with field trips to several wind-energy installations and public hearings. Ray Wassel and James Zucchetto also provided valuable help in framing questions, analyzing literature, and clarifying our thought processes and writings. Bryan Shipley helped to identify relevant literature and to summarize it for the committee. John Brown helped with meeting planning, including arranging field trips and helping to make sure that the committee arrived where it was supposed to be and returned in good condition. Jordan Crago supported the committee in so many ways that I cannot list them all, but they include literature searching and verification (along with Mirsada Karalic-Loncarevic), organizing drafts and committee comments, and keeping the committee housed and fed. Finally, Board Director James Reisa provided his usual wise counsel at difficult times, and his comments have improved the clarity and relevance of this report. We are grateful to them all.

Finally, I want to offer a personal note of appreciation to the committee and the staff. This was an extraordinary group of people, all with outstanding credentials but many points of view, who came together over the past two years to address an important and challenging topic. During this time they listened to each other, helped each other, and worked incredibly hard. It has been an honor to chair the committee, and my life has been enriched by the time and talents of my committee colleagues.

Paul G. Risser, Chair
Committee on Environmental Impacts of
Wind-Energy Projects

To: Paul Helgeson, WI Public Service Commission
From: Town of Union Wind Turbine Study Committee
November 6, 2007
Re: Health & Safety Research Questionnaire

Questions

1) The Townships get mixed messages from wind developers and Renew Wisconsin on the weight of the Draft Model Wind Ordinance for Wisconsin. Is the Draft Model Wind Ordinance for Wisconsin a law?

   Paul C. Helgeson, Senior Engineer Public Service Commission of Wisconsin answer received 1-2-07 at 12:41pm: 1. The draft Model Ordinance is a model that can be used by towns and counties as they see fit. It is not law.

2) In the Draft Model Wind Ordinance it states:

   PURPOSE The purpose of the Ordinance is to provide a regulatory scheme for the construction and operation of Wind Energy Facilities in the [Town/County], subject to reasonable restrictions, which will preserve the public health and safety.

   Who defines what a reasonable restriction is? Is it a law?

   Paul C. Helgeson, Senior Engineer Public Service Commission of Wisconsin answer received 1-2-07 at 12:41pm: 2. What is reasonable would be defined by local governments and the courts.

3) In regard to Wisconsin Statute 66.0401 item (a):

   Wisconsin Stat. § 66.0401(1) provides:

   (1) AUTHORITY TO RESTRICT SYSTEMS LIMITED. No county, city, town or village may place any restriction, either directly or in effect, on the installation or use of a solar energy system, as defined in s. 13.48(2)(h)1.g., or a wind energy system, as defined in [66.0403(1)(m)], unless the restriction satisfies one of the following conditions:

   (a) Serves to preserve or protect the public health or safety.

   (b) Does not significantly increase the cost of the system or significantly decrease its efficiency.

   (c) Allows for an alternative system of comparable cost and efficiency.

We have been given the impression that public health or safety must be supported by "peer-reviewed" and "credible" documentation. Is that a state law? NO ANSWER

4) Were "peer-reviewed" and "credible" documentation used in the Draft Model Wind Ordinance concerning safety and noise?

   NO ANSWER

5) What other State Statutes concerning public health and safety require "peer-reviewed" and "credible" documentation? NO ANSWER

6) In keeping with abiding with the legal requirements in the Wisconsin Statute 66.0401 we asked a Legislative Attorney what the State of Wisconsin's definition of Public Health and Safety was, and the answer was, "I think it is safe to say that "public health and safety" is an intentionally ambiguous term".

   He went on to say,

   "The reason these terms are intentionally ambiguous is that they involve judgments. They apply to situations either too various or too detailed as to be anticipated and dealt with specifically in laws. Where they apply to governmental bodies, such as the development of a wind ordinance by the Board of the Town of Union, they provide general guidance but intentionally leave the hands of the board members free to design an ordinance that meets the needs of that community, so long as the ordinance is reasonable.("Reasonable" is another ambiguous term, but it is the primary consideration in reviewing many kinds of governmental actions.)."

   Wouldn't this clearly say that the Town of Union Board and any other local government has the right to write an ordinance that protects their resident's health and safety without intimidation? NO ANSWER

7) In reading the Mission/Vision Statement for the Public Service Commission the last sentence states,

"In all of the above, we consider and balance diverse perspectives and we endeavor to protect the environment, and the public interest and the public health and welfare."

How do you feel you balance big business interests in Wind Development with the public health and welfare? NO ANSWER

Questions Specific to the Draft Model Wind Ordinance

8) Can you advise the process in creating the 2003 Draft Model Wind Ordinance?

Paul C. Helgeson, Senior Engineer Public Service Commission of Wisconsin answer received 1-2-07 at 12:41pm:

8) Process for creating the Draft Model Wind Ordinance is described in the Model Wind Ordinance Reference Guide and in documents that your group has obtained from the Commission.

9) Can you advise the process in creating the 2007 Draft Model Wind Ordinance?

Paul C. Helgeson, Senior Engineer Public Service Commission of Wisconsin answer received 1-2-07 at 12:41pm:

9) The Only significant changes are in section 5.3 and were made to be clearer and consistent with the PSCW sound measurement protocol for electric power plants. Some parts of the ordinance language were moved to the Reference Guide.

10)In the 2007 DRAFT Model Wind Ordinance it states: "the model ordinance was developed by agency staff and stakeholders." Please identify who these persons are. NO ANSWER

11)Why was the 2007 DRAFT Model Wind Ordinance put on the Department of Administration website ; then taken off; then put back on? This all occurred in the past 6 months. NO ANSWER

12)When was the 2007 DRAFT Model Wind Ordinance put the DOA website the first time; when was it taken off; when was it put back on the second time? NO ANSWER

13)What medical, scientific, and/or clinic data was utilized in the creation of each DRAFT ordinance? Please be specific. NO ANSWER

14)We understand that you and a female colleague at the Department of Administration were the co-authors of the 2007 DRAFT ordinance. Please identify other the co-author. NO ANSWER

15)Why were significant changes made to the noise portions of the 2007 Draft Ordinance?

Paul C. Helgeson, Senior Engineer Public Service Commission of Wisconsin answer received 1-2-07 at 12:41pm:

15) (See the answer to #9, above)

16)The World Health Organization recommends noise levels much different than your two DRAFT ordinances. Can you explain why you would not utilize their expertise and make your recommendation consistent to those recommended by the World Health Organization for community noise?

NO ANSWER

17)When a wind project is proposed, often times the developers suggest to local government, that they may receive revenue based on a variety of factors (PILOT Program; Shared revenue). Can you explain how the payments are determined for counties/townships based on incentives/megawatts produced or whatever criteria is used? Who actually pays this money out? How much has been paid out since 2000?

Paul C. Helgeson, Senior Engineer Public Service Commission of Wisconsin answer received 1-2-07 at 12:41pm:

17) Shared Revenue formulas are specified in Wis. Stat. § 79.04(6)(c) 1 and §79.04(7)(c)1. The formula is based on the nameplate capacity of the generators and the fact that a renewable resource is used. If the generators are in an unincorporated town, the town receives $1667 per MW per year and the county receives $2333 per MW per year. These are annual payments in place of property taxes. If you have further questions on the Shared Revenue program you should contact the Wisconsin Dept. of Revenue.

18) We have documented facts of the following: pending lawsuits worldwide, settled lawsuits right here in Wisconsin, neighbor easement agreements, bulldozed properties, property de-valuations, abandoned properties, nuisance payments, sound easements & payments, significant medical problems, quality of life issues, people relocating away from turbines, etc. With all these documented problems worldwide, it is clear to see that setbacks are the key to a successful wind project. The National Research Council recommends setbacks be at least ½ mile or so from residences. Many physicians are now recommending setbacks be at least 1 mile. **The Public Service Commission of Wisconsin** ("PSCW") has determined that it is important to site wind energy facilities carefully. The PSCW has also concluded that there is the potential for adverse environmental impacts when wind energy facilities are sited improperly (Public Service Commission of Wisconsin Advance Plan 7 Findings of Fact, pp. 22 – 23). As seen in Invenergy's Beech Ridge Wind Farm located in West Virginia, turbines are setback between one and four miles from residences. The project manager was quoted as follows: "At a distance of 1,000 feet, most potential negative impacts of wind turbines are significantly reduced. At a distance of one mile, these impacts are no longer a legitimate concern." Yet in Wisconsin we continue to see a recommendation from the DOA/Public Service Commission of 1,000 feet setback from residential housing. If your role is to protect the people and the environment of Wisconsin, why would you not recommend larger setbacks when you created your new 2007 DRAFT ordinance, knowing the problems that are documented worldwide related to insufficient setbacks? Please explain thoroughly. NO ANSWER

Here are the answers to the PSC questions.

From: Helgeson, Paul PSC [mailto:Paul.Helgeson@psc.state.wi.us]
Sent: Wednesday, January 02, 2008 12:41 PM
To: cathyjimb@eishome.com
Subject: H & S Research Questionnaire

Jim and Wind Turbine Study Group,

I have answered the questions that I can . I hope my answers are helpful.

1. The draft Model Ordinance is a model that can be used by towns and counties as they see fit. It is not law.
2. What is reasonable would be defined by local governments and the courts.

8) Process for creating the Draft Model Wind Ordinance is described in the Model Wind Ordinance Reference Guide and in documents that your group has obtained from the Commission.

9) The Only significant changes are in section 5.3 and were made to be clearer and consistent with the PSCW sound measurement protocol for electric power plants. Some parts of the ordinance language were moved to the Reference Guide.

15) (See the answer to #9, above)

17) Shared Revenue formulas are specified in Wis. Stat. § 79.04(6)(c) 1 and §79.04(7)(c)1. The formula is based on the nameplate capacity of the generators and the fact that a renewable resource is used. If the generators are in an unincorporated town, the town receives $1667 per MW per year and the county receives $2333 per MW per year. These are annual payments in place of property taxes. If you have further questions on the Shared Revenue program you should contact the Wisconsin Dept. of Revenue.

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