

May 2007

REPORT  
IN BRIEF

## Environmental Impacts of Wind-Energy Projects

As wind energy development continues to expand, federal, state and local agencies should adopt a consistent approach to evaluating the planning, regulation, and location of wind-energy projects. This National Research Council report proposes 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.

There has been rapid growth in the construction of wind-powered electricity generating facilities over the past 25 years in the United States. As the nation considers options for future energy development, environmental questions have emerged as important considerations. 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.

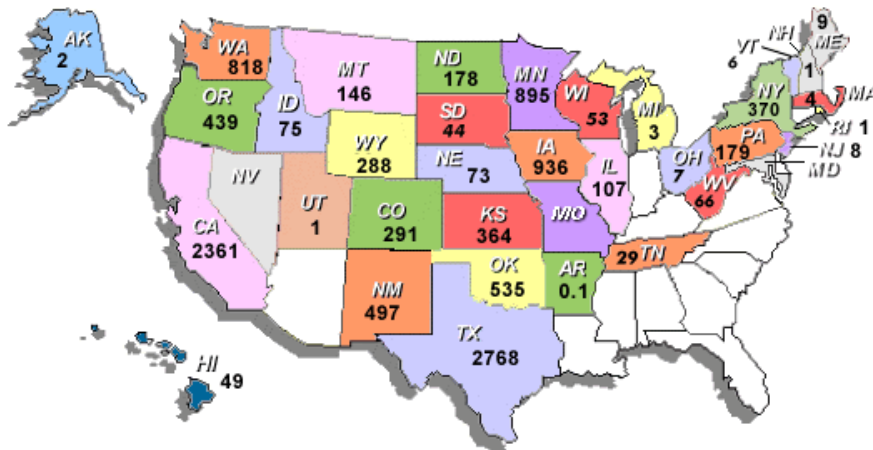
Wind energy provided about 1% of U.S. electricity in 2006 (Figure 1 shows distribution of installed capacity). An often-mentioned advantage of using wind-energy facilities is the reduction of thermal and atmospheric pollution associated with fossil fuel-based energy facilities. According to current projections for use of wind energy in 2020, use of the technology could reduce the energy sector's emissions of carbon dioxide by about 4.5% in 2020. However, more steps need to be taken to assess potentially

negative impacts—including threats to wildlife and sightlines—and evaluate tradeoffs between benefits and possible adverse environmental impacts.

The National Research Council was asked by Congress to review the positive and negative environmental impacts of wind-energy development, including effects on landscapes, views, wildlife, habitats, air pollution, and greenhouse gases.

### Federal Agencies Lack Experience Because Decisions Made Locally

Wind-energy projects exist in 36 states. California has had them since the early 1980s. Most wind turbines are approved through local zoning boards and state authorities. But most state governments, the Federal Energy Regulatory Commission, the Department of the Interior, and the Environmental Protection Agency do not have extensive experience with anticipating, reviewing, and assessing their impacts. The development of a more extensive knowledge base



**Figure 1.** Total installed U.S. wind-energy capacity in megawatts: 11,603 megawatts as of Dec 31, 2006. Source: American Wind Energy Association 2007.

THE NATIONAL ACADEMIES  
Advisers to the Nation on Science, Engineering, and Medicine

is needed so state and federal agencies can evaluate these impacts in order to better carry out their mandate to protect species and to weigh tradeoffs between the technology's environmental benefits and impacts.

The report urges federal and state agencies to take the environmental impacts of wind-energy more seriously as part of planning, locating, and regulating these facilities. This is because some bird and bat collisions with spinning blades and towers—especially along migration corridors—may begin to threaten local populations of some species if wind facilities rapidly expand over the next 20 years. The report notes that bat populations in the nation's Mid-Atlantic and several other regions of the country may be particularly at risk.

### Effects of Wind-Energy Projects on Wildlife

Development of wind power is on an upswing, particularly in the past seven years (see Figure 2). Out of a total of perhaps 1 billion birds killed annually as a result of human structures, vehicles and activities, somewhere between 20,000 and 37,000 died in 2003 as a result of collisions with wind-energy facilities.

However, the crucial issue is whether these impacts affect whole populations of certain species. At the current level of U.S. installed wind capacity, the report found no evidence of significant impacts on bird populations. One possible exception is certain birds of prey in California whose threatened status may be aggravated by collisions with older wind-energy technology at one area in the state. In light of the lack of follow-up studies of environmental impacts of these facilities, more careful tracking of bird and bat populations, behavior, migration corridors, and other factors that may affect their risk of collisions with turbines is warranted, especially for threatened or endangered species.

To provide a systematic approach to wind energy and its effects, the report's evaluation guide (*see next page*) recommends using systematic pre- and post-construction studies to explore potential wildlife and other impacts and improve how such facilities are built, located, and operated.

### Potential Impacts of Wind-Energy Projects on Property Values

Perceptions of wind-energy projects, like other potentially controversial developments, vary depending on the characteristics of the surrounding community. Residents living near proposed facilities may resist having their views and sightlines altered. The potential nuisance created by flickering shadows resulting from spinning blades has been raised in other countries with wind-energy facilities but has not been a significant issue to date in the United States.

Several research studies failed to detect an

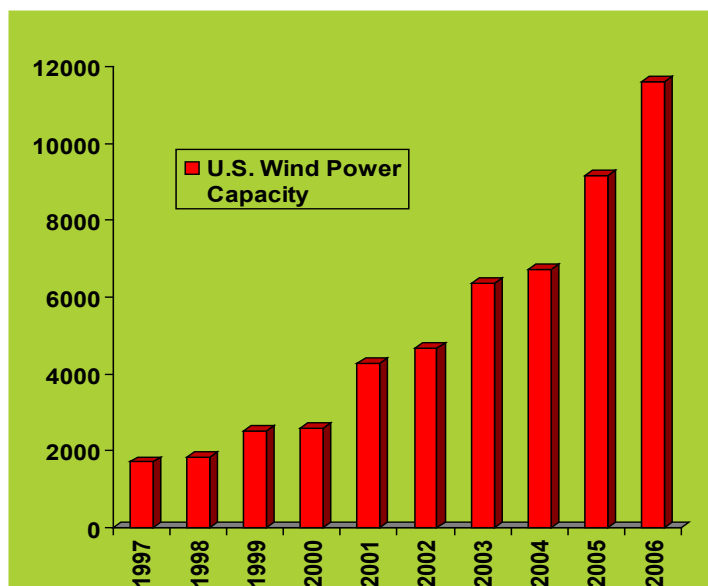
average effect of wind-energy facilities on property values within a ten-mile radius of the sites. Despite the difficulty of reaching reliable conclusions about property value impacts, it is possible to identify some of the key factors involved. Aesthetic impacts could be important, especially when a property is valuable for a purpose incompatible with wind-energy projects, such as to experience life in a remote and relatively untouched area. In this scenario a view that includes a wind-energy project may detract from

property values. On the other hand, to the extent that a wind-energy project contributes to the prosperity of an area, it may help to bring in amenities and, therefore, may enhance property values. In addition, landowners can be paid about \$3,000 per year per turbine on their property.

Because the construction of wind installations in the United States is a relatively recent phenomenon, the long-term effects of wind-energy projects on property values are difficult to assess, according to the report. While property values may be initially affected by a wind-energy project, the effect may diminish as the project becomes an accepted part of the landscape.

### Consideration of Other Ecological Impacts

Although research and monitoring studies are not extensive, a review of existing studies indicates that adverse effects of wind-energy facilities on ecosystems



**Figure 2.** U.S. installed wind power capacity (in megawatts) has increased sharply over the past 10 years. Source: American Wind Energy Association 2007.

## Guide for Evaluating Wind-Energy Projects

### Some elements to consider in policy, planning, and public relations

1. Have mechanisms been established to provide necessary information to interested and affected parties, and to seek meaningful input from them as wind-energy projects are planned and implemented? Are developers required to provide early notification of their intent to develop wind energy?
2. Are procedures—including policies and regulations—in place for evaluating the impacts of wind-energy projects that cross jurisdictional boundaries?
3. Is guidance available to developers, regulators, and the public about what kinds of information are needed for review, what degrees of adverse and beneficial effects of proposed wind-energy developments should be considered critical in evaluating a proposed project, and how competing costs and benefits of a proposed project should be weighed with regard to that proposal only, or by comparison with likely alternatives?
4. Are regional planning documents available that provide guidance on the quality of wind resources, capacity of transmission options, potential markets, major areas of concern, and tradeoffs that should be considered?

### Legal and Regulatory Considerations

1. Are wind-energy guidelines and regulations issued by different federal agencies compatible, are those guidelines and regulations aligned with other federal regulating rules and regulations, and do the guidelines and regulations follow acceptable scientific principles when establishing data requirements?
2. Does the review process include steps that explicitly address the cumulative impacts of wind-energy projects over space and time; that is, by reviewing each new project in the context of other existing and planned projects in the region?

### Evaluation of Impacts

1. Are the biological, aesthetic, cultural, and socioeconomic attributes of the region sufficiently well known to allow an accurate assessment of the environmental impacts of the wind-energy project, and to distinguish among the potential sites considered during the site selection process? Are there species, habitats, recreational areas, or cultural sites of special interest or concern that will be affected by the project? Are there key gaps in the needed information that should be addressed with further research before a project is approved or to guide the operation of an approved project?

### Environmental Impacts

1. What environmental mitigation measures will be taken and how will their effectiveness be measured? Are there any legal requirements for such measures (e.g., habitat conservation plans)? Are any listed species at risk from the proposed facility?
2. How and by whom will the environmental impacts be evaluated once the project is in operation? If these evaluations indicate needed changes in the operation of the facility, how will such a decision be made and how will their implementation be assured?
3. What pre-siting studies for site selection and pre-construction studies for impact assessment and mitigation planning are required?
4. What post-construction studies, with appropriate controls, are required to evaluate impacts, modify mitigation if needed, and improve future planning?

### Impacts on Human Health and Well-Being

1. Have pre-construction noise surveys been conducted to determine the background noise levels? Will technical assessments of the operational noise levels be conducted? Is there an established process to resolve complaints from the operation of the turbines?
2. Is there a process in place to address complaints of shadow flicker and does the operator use the best software programs to minimize any flicker?

### Aesthetic Impacts

1. Has the project planning involved professional assessment of potential visual impacts, using established techniques such as those recommended by the U.S. Forest Service or U.S. Bureau of Land Management?
2. How have the public and the locally affected inhabitants been involved in evaluating the potential aesthetic and visual impacts?

### Cultural Impacts

1. Has there been expert consideration of the possible impacts of the project on recreational opportunities and on historical, sacred, and archeological sites?

### Economic and Fiscal Impacts

1. Have the direct economic impacts of the project been accurately evaluated, including the types and pay scales of the jobs produced during the construction and operational phases, the taxes that will be produced, and costs to the public?
2. Has there been a careful explication of the indirect economic costs and benefits, including opportunity costs and the distribution of monetary and non-monetary benefits and costs?
3. Are the guarantees and mitigation measures designed to fit the project and address the interests of the community members and the local jurisdictions?

### Electromagnetic Interference

1. Has the developer assessed the possibility of radio, television, and radar interference?

### Cumulative Effects

1. How will cumulative effects be assessed, and what will be included in that assessment (i.e., the effects only of other wind-energy installations, or of all other electricity generators, or of all other anthropogenic impacts on the area)? Have the spatial and temporal scales of the cumulative-effects assessment been specified?

have occurred. The construction and maintenance required to install wind turbines and roads alters ecosystems through the clearing of vegetation, soil disruption, and the potential for erosion and noise. These changes can lead to habitat loss and fragmentation for forest-dependent species. This impact is particularly important in the Mid-Atlantic Highlands, because wind-energy projects there have all been constructed or proposed in forested areas.

Plants and animals throughout an ecosystem respond differently to changes in forests, and although no deaths of animals listed under the Endangered Species Act have been recorded to date, agencies should evaluate this possibility. This knowledge should be weighed using the evaluation guide (*see previous page*) outlined in the report to minimize ecological impacts and inform decisions on planning, siting, and operation.

### **Comparative Research on Environmental Impacts is Crucial**

As policymakers weigh strategies for future energy development, an ability to compare the environmental impacts and benefits of various options will improve the information base for decisions. But a lack of side-by-side information on the environmental costs and benefits of wind-energy development compared with other types of energy facilities makes it difficult to project impacts on wildlife and ecosystems for the different energy options policymakers and developers are considering.

To address this lack of information, the report's evaluation guide will help assess the environmental effects of wind-

energy projects before they are built and after installation. Such information will facilitate comparisons with other energy options. The guide contains a matrix, which is not pictured, for coordinating the review of wind-energy projects across federal, regional/state and local governments. It addresses a range of issues including legal, regulatory, health, environmental, aesthetic, cultural, and economic impacts.

Objective, systematic methods of assessing aesthetic impacts, including visual impacts, are available, such as some methods used by the U.S. Fish & Wildlife Service. They can and should be adapted to use for wind-energy projects.

#### **The Guide for Evaluation of Wind-Energy**

**Projects** emphasizes the need to create opportunities for public input by incorporating participation by those whose well-being may be affected by siting decisions so these impacts can be minimized or avoided. The guide should be routinely used to help organize regulatory reviews and encourage public input. As a result, the public, policymakers, energy developers, state and federal agencies, and other interested groups will have a richer information base for decision-making.

In addition, government agencies could use this guide to develop methods for addressing tradeoffs between the benefits, costs, and environmental impacts of wind-energy facilities in comparison with other energy options, which are seldom evaluated this comprehensively. This will help inform future choices about which types of energy development should be pursued to meet the nation's growing needs.



---

**Committee on Environmental Impacts of Wind-Energy Projects:** **Paul Risser (Chair)**, University of Oklahoma; **Ingrid Burke**, University of Colorado; **Christopher Clark**, Cornell University; **Mary English**, University of Tennessee; **Sidney Gauthreaux, Jr.**, Clemson University; **Sherri Goodman**, Center for Naval Analyses; **John Hayes**, University of Florida; **Arpad Horvath**, University of California, Berkeley; **Thomas Kunz**, Boston University; **Lance Manuel**, University of Texas, Austin; **Erik Lundtang Petersen**, Risø National Laboratory, Denmark; **Dale Strickland**, Western EcoSystems Technology, Inc.; **Jean Vissering**, Jean Vissering Landscape Architecture; **James Roderick Webb**, University of Virginia; and **Robert Whitmore**, West Virginia University

**This report brief was prepared by the National Research Council based on the committee's report.** For more information or copies, contact the Board on Environmental Studies and Toxicology at (202) 334-3060 or visit <http://nationalacademies.org/best>. Copies of *Environmental Impacts of Wind-Energy Projects* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; [www.nap.edu](http://www.nap.edu).

This study was supported by funds from the Executive Office the President, Council on Environmental Quality.

*Permission granted to reproduce this brief in its entirety with no additions or alterations.*