ENVIRONMENTAL IMPACTS OF WIND POWER

D. J. Lew
International Institute for Energy Conservation, Bangkok, Thailand

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Contents

1. Introduction

Wind is the world's fastest growing energy source, with annual growth of 24–35% between 1995 and 1998. Installed capacity at the end of 1997 reached over 8710 MW. In the middle of 1997, Germany became the world leader in wind power development with over 2000 MW of installed capacity, surpassing the US. This growth was fueled by very favorable national energy policies for wind energy development. In 1997, Denmark topped 1000 MW of wind power capacity, providing 7% of the country's electricity demand. Further strong growth in Europe is likely, following a pledge by the European Union to increase wind capacity on the continent to 10 000 MW by the year 2010.

The US, formerly a leader in wind power development, had few new installations in the middle of the 1990s, due to uncertainties over utility restructuring. However, wind development is beginning to grow again, with almost 800 MW of new capacity scheduled to become operational by the end of 1999.

The fastest-growing market for wind in the middle of the 1990s was India. This was a result of the government's commitment to renewable energy through its establishment of a Ministry of Non-Conventional Energy Sources and enactment of favorable renewable energy policies. Wind activity in some other developing countries, such as China, is growing slowly; meanwhile some of these governments are investigating renewable energy policies, which may accelerate growth in their countries.

As wind power development accelerates, the environmental impact of this energy source is brought more seriously under consideration. Wind power is hailed for its significant positive impacts in offsetting carbon dioxide and air pollution emissions from fossil-fueled power plants or nuclear safety and waste disposal problems from nuclear power plants. However, despite the fact that wind energy has much less of an environmental impact than fossil fuel or nuclear energy sources, there is nonetheless a demonstrated impact on wildlife and the general public. This may take the form of visual and noise impacts on the public, electromagnetic interference, land impacts and erosion, interference with wildlife habitats or increased bird mortality.

The most common protests against wind power development are the visual and noise impacts on people. This is especially a problem in Europe, where wind power development tends to occur closer to population centers. These effects are difficult to measure and the visual impact can be perceived as a positive or negative impact.

The subjectivity of the visual and noise impacts makes them difficult for developers and designers to understand and work around; on the other hand, it is fortunate that some of the main impacts of wind power development can be lessened through some simple forethought and designs that take the human factor into account.Avian impacts can be another significant issue, especially in the US, where wind farms near golden eagle habitats and migration paths have caused deaths of this protected species. Although bird fatalities are reported to be higher in Europe than in the US, the European fatalities tend to be common birds, whose populations are not significantly threatened.

2. Emissions

Wind power differs from conventional power generation in that it does not involve the emissions of carbon dioxide or air pollutants such as nitrogen oxides and sulfur oxides. The only emissions in wind power development are those involved in manufacture of the wind turbines and construction of the wind farms. These are negligible in comparison to the emissions from conventional power generation.

3. Water Use

Because wind turbines do not involve thermal power generation where cooling is necessary, water supplies are not needed for their operation. Very small amounts of water may be necessary in arid areas for cleaning the blades. This is negligible in comparison to the water necessary for cooling of conventional power plants.

4. Landscape and Visual Impact

Of the environmental impacts of wind power development, the most commonly cited impact is the visual impact that wind turbines have on the landscape. This visual impact can be positive or negative, depending on the perception of the viewer.

The visual impact of a wind farm is a function of the number of turbines, turbine size and design, color, and the layout of the wind farm. Wind turbines are comparable to the size of other man-made structures. However, the technology is relatively new to most communities and the public is generally unaccustomed to the view.

4.1. Public Acceptance

The impact on people is part of the NIMBY (Not In My BackYard) phenomenon that tends to thwart development. This is a consequence of the fact that the people nearest the development project bear all of the impacts of the project while many people share the benefits. Often, public acceptance of wind energy is high, but the public simply doesn't want the wind turbines near their own community.

Wind turbines are not too different from many other structures such as buildings, power plants, transmission lines, or lighthouses (See Figure 1). Like transmission lines or lighthouses, wind turbines are often sited in areas that have not been developed, and which may be areas of scenic beauty. The intrusion of a large man-made structure in a rural area may be displeasing to people. However, most people are so accustomed to the sight of telephone poles or transmission lines that those structures are barely noticeable. An unfamiliar structure such as a wind turbine, which moves when it is windy, will be very noticeable to the public.

In general, public acceptance of wind power development tends to be more difficult with people who object to wind energy or renewable energy and less of a problem with people who favor renewable energy. Public opinion thus tends to polarize with some very much in favor of wind development and some very strongly opposed. Because the public is relatively unfamiliar and unaccustomed to wind technology, their opinions are easily influenced by the media.

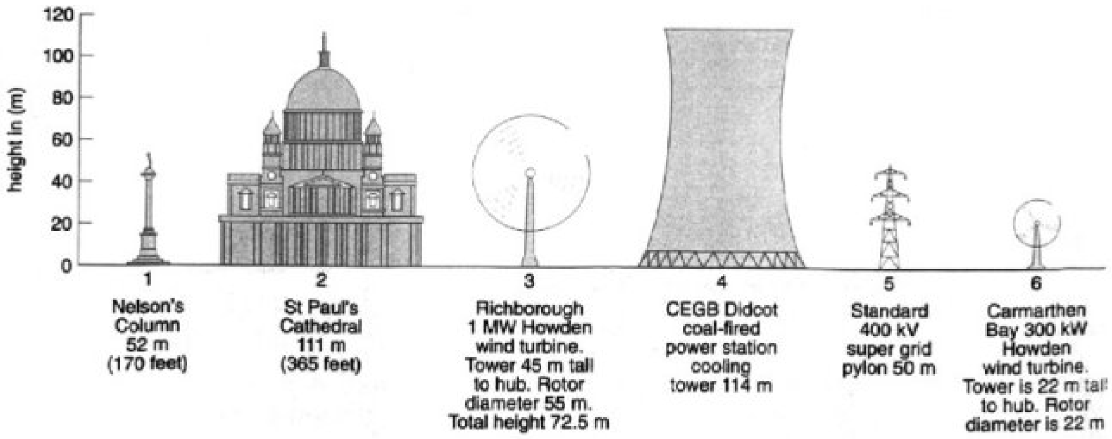

Figure 1. Comparison of wind turbines to other man-made structures.(Boyle G. (1996)).

4.1.1. Usefulness to Society

In California, where several large wind farms containing thousands of wind turbines are seen by hundreds of thousands of people every day, the issue of inoperative turbines adds to negative public opinion. Because one inoperative turbine is easily noticeable in a farm of spinning turbines, public reaction is to wonder why one turbine is not spinning instead of marveling at the thousands of others, which are spinning.

The general public may be unaware that a single wind turbine can be inoperative for a number of reasons that have nothing to do with reliability or need for repair: a turbine may be down for scheduled maintenance; there may be lower winds at that particular site; the turbine may have a higher cut-in speed than surrounding turbines; the electricity demand might be low; or the grid might be down. Regardless of the reason, the visual impact of inoperative turbines increases public perception that the turbines are unreliable or not useful and therefore not worth the visual intrusion on the landscape.

This tends to be less of a problem in Europe where many turbines have been installed singly or in small groups and thus are less likely to be noticeable when inoperative, or where the wind farms have been installed more recently with state-of-the-art, very reliable technology.

Usefulness tends to play a major role in public acceptance of a wind power plant both in the US and Europe. Surveys in Sweden show that the public is more interested in siting the wind turbines where they will be most effective and not where they will be least visible. The Swedish results also show that the public is strongly influenced by information about the performance of the wind power plant. In line with this thinking, many small wind turbine installations and larger wind farms in Europe have booths, which give information about the projects.

4.1.2. Acceptance Levels During the Project Cycle

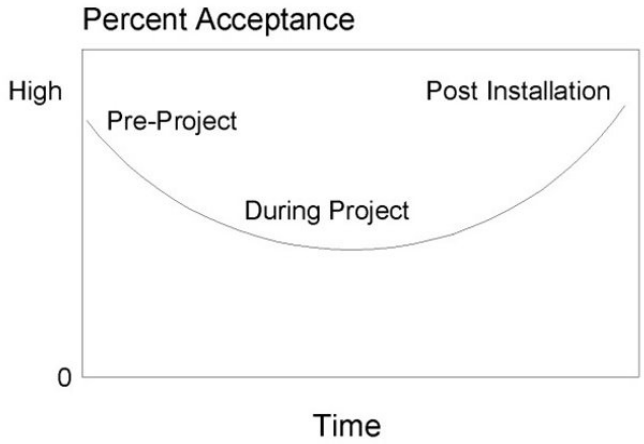

Figure 2. Acceptance of wind energy project before proposal, after proposal, and after installation (Energy Connection, Delft, The Netherlands)

Surveys from the UK, the Netherlands, and the US show that wind energy generally has high approval from the public, but that public acceptance decreases once a project has been proposed, and then is reestablished once the project has been completed. See Figure 2.Once a project is installed, it is often found that the perceptions that fueled the protests were misconceptions or a fear of the unknown. People tend to become accustomed to the visual and noise impact, and though they might be able to hear the turbines or find the visual impact not pleasing, acceptance of the wind power plants tends to be high after installation.

4.2. Shadow Flicker

In Europe, where turbines are often sited close to communities and households, the shadow of the moving blades may be bothersome. There is a concern in some areas that the flickering of the shadow will trigger epileptic seizures. However, photosensitivity epilepsy is extremely rare.

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Biographical Sketch

Debra J. Lew is Senior Energy Advisor to the Asia office of the International Institute for Energy Conservation in Bangkok, Thailand as the, where she established a renewable energy program, focusing on market-based policies, project development and capacity building in Asia. After undergraduate (Massachusetts Institute of Technology, 1988) training in electrical engineering and physics and during graduate (Stanford University, 1990, 1994) training in applied physics, Lew was a volunteer and then consultant with the Union of Concerned Scientists in Berkeley, California where she moved from working on experimental solid state physics to renewable energy and energy efficiency, specifically in biomass conversion to transportation fuels and use of fuel cells. After graduation, she was a Postdoctoral Research Associate at the Center for Energy and Environmental Studies at Princeton University where she modeled utility-scale, baseload wind power/storage systems for China. She then worked at the US National Renewable Energy Laboratory as a Postdoctoral Research Associate with the National Wind Technology Center's International Team, performing technical and economic performance and optimization analyses of hybrid renewable energy systems for households and villages in China and Chile. Her research interests include energy policy; aspects of dissemination of renewable energy systems, including market development, technology transfer, and management issues; and climate change. She has authored over 20 publications and reports, including contributions to a book and encyclopedia.