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TURBULENT ENERGY: THE PROS AND CONS OF WIND POWER

Michel Charron
Science and Technology Division

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INTRODUCTION

Wind power is the fastest-growing source of electricity in the world,[(1)] and is expected by many to become the leading energy alternative to fossil fuels.[(2)] As part of its efforts to meet Canada's Kyoto commitment for the reduction of greenhouse gases (GHGs), the federal government is strongly promoting alternative and renewable energies, chiefly wind power.[(3)] Many provincial and territorial governments are doing the same. The 2001 federal budget created the Wind Power Production Incentive (WPPI), which Budget 2005 increased to $200 million over five years.

Wind-driven electricity production is not a new technology. The industry is now using third-generation modern turbines, and improved materials and control systems are increasing the efficiency of wind farming. In Denmark, wind power accounts for 20% of the electricity consumed, and in some parts of Germany it contributes as much as 50% to total electricity production – statistics that make it difficult to think of wind as an "alternative" energy in these countries.

Wind power undoubtedly owes part of its leadership position among alternative energies, and its favour with governments and other regulators, to successful promotion and

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(1) According to the Canadian Wind Energy Association (CanWEA) (http://www.canwea.ca).

(2) Robert L. Bradley Jr., *Renewable Energy: Not Cheap, Not "Green,"* Cato Policy Analysis No. 280, Cato Institute, Washington, 12 August 1997, p. 2.

(3) In *Moving Forward on Climate Change: A Plan for Honouring our Kyoto Commitment*, the federal government proposes $600 million in direct incentives for alternative energy. Canada ratified the Kyoto Protocol on 12 December 2002, thereby pledging to reduce average annual GHG emissions for the period 2008 to 2012 to approximately 560 Megatonnes (Mt) of CO_2 equivalent, or 6% below 1990 levels. Since 1990, Canada's economy, with which GHG emissions are correlated, has grown at a faster rate than expected so that, rather than declining, the country's GHG emissions are more than 20% above 1990 levels. As a result, the Government of Canada now estimates that in order to achieve its 560 Mt target, the country will have to reduce its annual GHG emissions by more than 280 Mt for a reporting period that begins in less than three years.

marketing of its merits. In fact, it is often touted in the media, by governments, the wind industry and many environmental groups as a near-panacea for current world energy and global climate-change problems.

Wind power has its critics, but their arguments do not seem to get the same media or government attention as those of wind power proponents. While many of the detractors are motivated by evident economic or political considerations, this is not always the case. Regardless, the arguments they present serve to highlight that wind power is not without its challenges. Perhaps one of the most surprising developments in the debate is the large rift that has developed over wind power within the environmental community itself. Renowned environmentalist David Suzuki drew both praise and ire for an opinion piece in which he acknowledged the validity of many of the anti-wind arguments but urged people to look beyond the problems to the greater good of fighting climate change.(4) In Suzuki's words:

> Climate change … cannot be solved through good intentions. It will take a radical change in the way we produce and consume energy … But first we must accept that all forms of energy have associated costs … We can't shout about global warming and then shout even louder about the "dangers" of windmills.

It is clear that wind power must be part of the solution to the challenges of climate change and energy demands; but, as with all forms of electricity generation, wind power too has its drawbacks.

WIND POWER BASICS

Wind contains kinetic energy that wind turbines capture and convert to electricity. Wind turbines have a *nameplate capacity*, which is the amount of electricity a turbine can generate were it to operate continuously and at full capacity. In fact, however, even an ideal turbine captures only about 60% of the total energy available in the wind and there are other losses, through friction and electrical resistance for example.(5) Since wind turbines do not

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(4) David Suzuki, "The Beauty of Wind Farms," *New Scientist*, Issue 2495, 16 April 2005, p. 20.

(5) Since the turbine actually slows the wind passing through it, the more energy it harvests, the slower the wind. Capturing 100% of the energy would stop the wind and the movement of the blades. This is known as Betz' law.

operate at full capacity all of the time, a *capacity factor* is used to express operational efficiency. A turbine's capacity factor depends on many things – some inherent to the turbine design, such as cut-in and cut-out wind speeds, and many others related to the nature of the wind and "siting" of the turbines at a particular installation.

Developers of wind power projects have been known to claim average efficiency ratings or capacity factors of 35% or more for land-based projects. Typical capacity factors of operational turbines, however, are 20% to 30% on land and 35% or more offshore.[(6)] It is important to note that the lower capacity factor of a wind turbine relative to other forms of generation is a matter of economical design.[(7)] Wind turbines can be made with a capacity factor of 60% to 80% by using a very large rotor and a very small generator, but these would produce very little electricity. Operators look to minimize the cost per unit of electricity generated by using a larger generator that requires stronger winds and accepting that the capacity factor will be lower as a result.[(8)]

CURRENT CANADIAN SITUATION

Hydro power provides over 60% of Canadian electricity, with nuclear, coal and natural gas contributing some 35% to the total, and wind power generating just 0.2%.[(9)] In 2004, Canada produced 567.6 terawatt-hours (TWh)[(10)] of electricity, imported 29 TWh, and exported 34 TWh. Domestic consumption was approximately 562.6 TWh.[(11)] The same year there was 450 megawatts (MW) of nameplate wind power capacity in Canada, which generated approximately 1.2 TWh of electricity. In 2003, the generation of electricity in Canada released 134 Mt of CO_2 equivalent to the atmosphere.

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(6) Danish Wind Industry Association, *Annual Energy Output from a Wind Turbine*, Copenhagen, updated 19 September 2003 (http://www.windpower.org/en/tour/wres/annu.htm).

(7) Natural gas and nuclear facilities typically have capacity factors in the range of 60% to 80%.

(8) American Wind Energy Association, *wind web tutorial*, "Wind energy basics" (http://www.awea.org/faq/tutorial/wwt_basics.html#What%20is%20capacity%20factor).

(9) According to CanWEA, "other sources" (likely biomass, biogas, solar, and tidal) contribute some 3.8% to the total electricity produced in Canada.

(10) A terawatt-hour is a trillion (1,000,000,000,000) watt-hours. A 100-watt bulb lit for one hour requires 100 watt-hours of electricity.

(11) Statistics Canada, *Energy Statistics Handbook: Fourth Quarter 2004*, Cat. No. 57-601-XIE, Ottawa, May 2005.

As of June 2005, the total nameplate wind power generating capacity in Canada was 471 MW, excluding small-scale (300 W to 300 kW) or personal generators.(12) Through the WPPI, the federal government hopes to see Canada's commissioned wind power capacity increase to 4,000 MW by 2010.(13)

ECONOMIC CONSIDERATIONS

According to the United States Federal Energy Regulatory Commission, the capital cost of installing wind energy systems has decreased since the early 1980s, from over US$2,000/kW to the current level of approximately US$800 to US$1,100/kW.(14) Capital costs depend on many factors, including the size of the installation, the accessibility of the site, the chosen technologies, and the cost of supporting infrastructure. The strength of the wind resource and a well-matched system design are also important in determining installation costs, as these elements determine the capacity factor. Since the majority of installation costs for wind power are fixed costs, increased output (capacity factor and/or number of turbines) directly lowers the per-unit cost. CanWEA estimates the cost of generating electricity from wind at approximately $0.06 to $0.12 per kW/h without subsidy.(15) A recent report for Hydro Quebec suggests that the CanWEA estimate is in line with other reported costs, particularly from the United States.(16)

Developers of the proposed Nai Kun offshore wind farm, a 700-MW wind power project proposed for the Hecate Strait between Haida Gwaii and Prince Rupert on Canada's west coast, claim that the electricity generated by their state-of-the-art facility will cost the same as that generated by a modern natural-gas-fired plant. Despite this claim and the decreasing cost of wind power, traditional sources of electricity generally have lower production costs, at least in North America (with the possible exception of nuclear power). The federal government

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(12) CanWEA estimates that there are between 2,200 and 2,500 of these small units in use in Canada with an estimated combined capacity of 1.8 to 4.5 MW (http://www.smallwindenergy.ca/en/Overview/SmallWindCanada.html).

(13) The WPPI provides direct financial support to wind power developers and operators in an amount ranging from 0.8 to 1.2 cents per kW/h.

(14) Federal Energy Regulatory Commission, *Assessing the State of Wind Energy in Wholesale Interstate Markets*, FERC Staff Briefing Paper: Docket No. AD04-13-000, Washington, 22 November 2004, p. 15.

(15) CanWEA, *Frequently Asked Questions on Wind Energy*, "Wind Energy Economics" (http://www.canwea.ca/en/faq.html#economics).

(16) Merrimack Energy Group, Inc., *The Competitive Cost of Wind Power*, prepared for Hydro Quebec Distribution, Request R-3569-2005, Montréal, April 2005, p. 2 (http://www.hydroquebec.com/distribution/fr/marchequebecois/requete/hqd-02_doc04.pdf).

estimates that the amount of incentive provided through the WPPI is approximately half of "the current estimated cost premium for wind energy in Canada for facilities with good wind sources."(17) This economic reality, coupled with a North American over-production of electricity in the early to mid-1990s, provided strong arguments against wind power.(18) However, as rotating power failures and brown-outs in the late 1990s and early 2000s have shown, there is now a potential North American shortage of electricity. With governments in some jurisdictions regulating air emissions in a way that greatly limits the output from coal-fired plants, or even results in the closure of some of those plants, and with many nuclear facilities nearing the end of their service life, the possibility of a serious shortage is growing.(19)

In some proposals and marketing materials, wind power producers have presented production costs that are made possible only because of government subsidies. These subsidies are both direct, such as the federal WPPI (0.8 cent to 1.2 cents per kW/h), and indirect, such as the Greening Government program, which includes a proposal to purchase 20% of the federal government's energy from renewable sources (regardless of cost). The Nai Kun developers' comparison of their proposed facility's electricity prices to gas-generated electricity prices, for example, includes a subsidy of 1 cent per kW/h from the WPPI and 0.5 cent per MWh for the sale of "green credits" for reduced CO_2 emissions.(20) Wind power opponents claim that these lowered costs make wind proposals seem more attractive and feasible than they truly are.

Proponents of wind power have also been accused of presenting costs based on unrealistic capacity factors. For example, a current offshore wind farm proposal predicts that the facility will operate with a 47% capacity factor – well above the 35% capacity factor that the Danish wind energy industry claims to be typical for offshore farms. Suspect capacity factor claims can be easily identified, though, since wind industry associations promote realistic capacity factors. For land-based turbines, the Danish association claims typical capacity factors of 20% to 30%; CanWEA estimates 30%; and the American Wind Energy Association between 25% and 40%. These capacity factors, though much lower than for a typical thermal plant, are intentional and economically efficient, as discussed previously.

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(17) Natural Resources Canada, "Wind Power Production Incentive (WPPI)," *The Canadian Renewable Energy Network (CanREN)*, updated 6 April 2005 (http://www.canren.gc.ca/programs/index.asp?CaId=107&PgId=622).

(18) Bradley (1997).

(19) For example, the Government of Ontario recently had to postpone the scheduled closing of the remaining coal-fired plants in the province, due mainly to a lack of alternative generating capacity.

(20) Based on emission reductions from a wind power facility as compared to a combined-cycle gas turbine, and a price of US$10 per tonne for CO_2 credits.

ENVIRONMENTAL ISSUES

A. A Renewable Resource

Wind is a renewable resource in that it is generated, at the global scale, by the sun. The number of places in Canada and throughout the world where there is enough wind on a consistent basis to "harvest" is limited. Nevertheless, the Canadian Wind Energy Association (CanWEA) states that the capacity exists to generate up to 20% of the country's electricity with wind, and it is currently promoting investment in wind energy with a goal of achieving 10,000 MW of capacity by 2010. (This target includes the 4,000 MW expected under the WPPI.) Recent research indicates that, globally, there is sufficient exploitable wind resource to meet current global electricity demand several times over.(21)

While wind may be an endless power supply, it is also intermittent, which means that generation is not continuous or on demand. As a result, wind power systems typically cannot be used to ensure that baseload requirements will be met. Wind power must be used in conjunction with other power sources such as thermal, hydroelectric or nuclear. The Vice President of Sustainable Development for TransAlta has stated that wind power will never replace traditional sources of electricity, but rather will complement them.(22) Some argue that intermittency could be addressed by integrating a large number of wind power facilities over great geographic areas. The logic is that such a grid would always be receiving power from at least some of its generators.

A final limitation of the wind resource is that turbines slow the wind and increase its turbulence as they extract its power. This reduction in wind speed limits the density of turbines in a wind farm setting, as it is inefficient to place one turbine in the wind-shadow of another.

B. "Green" Power

Perhaps the biggest and best-known advantage of wind turbines is that their operation is emissions-free. This means that the turbines generate electricity without creating or

(21) C. L. Archer and M. Z. Jacobson, "Evaluation of Global Wind Power," *Journal of Geophysical Research – Atmosphere*, 2005, accepted for publication.

(22) Bob Page, "Winds of Change: Why would a perfectly respectable power company like TransAlta invest in wind power? Because it makes environmental and economic sense," *National Post* [Toronto], 8 November 2002, p. FP 11.

emitting to the atmosphere any greenhouse gases, smog-generating pollutants, airborne toxic substances such as mercury, or acid-rain precursors. Therefore, their operation does not contribute to enhanced global warming or to air-quality-related health issues. However, emissions-free operation should not be taken to mean that harnessing wind power is entirely pollution-free.(23) The operation and maintenance of turbines, as with any electrical generation system, requires large volumes of lubricants, degreasers, and fluids for transformers. As wind farms are typically constructed in rural or limited-infrastructure areas, these potentially polluting substances require transportation to and from the installation and likely on-site storage. Releases are inevitable.

While the operation of wind turbines is emissions-free, the manufacture of the blades, towers, generators, etc., remains an energy-intensive industrial activity that some argue should be considered when assessing the environmental impact of a new wind power facility. Similarly, some feel that the emissions from any supplementary fossil-fuel use required to ensure reliable power generation, given the intermittency of wind power, should also be taken into account.

Pollution produced during the manufacture and installation of turbines and their infrastructure is their main environmental effect on a life-cycle basis, and this point is used by wind power opponents to underline that the electricity is not truly emissions-free.(24) However, the studies summarized in a European Commission project(25) show that the construction of coal-fired power plants is similarly costly to the environment and human health. In the case of the latter power systems, though, the impacts of plant manufacture are minimal when compared to the operational and resource extraction impacts. A fair comparison between power sources would require that the same life-cycle components be considered for all. In 1999, the pan-European power company Vattenfall published a life-cycle analysis including plant construction costs for all its current and potential sources of electricity.(26) The report indicates

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(23) CanWEA claims that "Wind energy is 100% pollution free …" in *A powerful Choice* (http://www.canwea.ca/downloads/en/PDFS/CanWEA_brochure.pdf).

(24) International Council for Local Environmental Initiatives (ICLEI), *FAQs about Wind Power* (http://www.greenpowergovs.org/wind/FAQs.html).

(25) The ExternE: Externalities of Energy project of the European Commission was the first comprehensive attempt to evaluate the external costs associated with a range of different fuel cycles (http://externe.jrc.es/index.html).

(26) *Vattenfall's Life Cycle Studies of Electricity*, Vattenfall AB, Stockholm, 1999 (http://www.sylvatica.com/lcaeng.pdf).

that the construction of a gas turbine plant has a similar environmental impact per kWh of electricity produced as a wind farm, and that the construction of a nuclear facility is even more damaging.(27) The report's findings show that for all power sources except hydro, solar and wind, fuel production and plant operation are the major sources of environmental impact; in most cases, these dwarf the effects of plant construction.

Finally, computer models of very large wind farms indicate that they could modify local climate.(28) Wind farms could increase the mixing of air at turbine height (e.g., 80 m) with air at the surface. The temperature, wind speed, and moisture content of these layers can be quite different, especially in the early morning hours, and mixing will blend them. This could result in increased evaporation and higher daily minimum temperatures near the surface.

C. Visual and Noise Pollution

Visual and noise pollution are two of the most significant problems associated with wind power, and have drawn criticism even within the environmental community. In order for wind power production to be economically viable, relatively large wind farms are needed. However, a cluster of dozens or even hundreds of wind turbines reaching 50 to 90 metres into the sky is visible from great distances – especially given that the necessary wind resources are often found in areas that are open and relatively flat. Viewed from a distance, a collection of turbines may interrupt a vista otherwise devoid of any industrial structures. Viewed from close, the turbines are a towering and dominating presence. Even renowned environmental activist David Suzuki tacitly acknowledged that some will find wind turbines visually offensive when he encouraged people to see beyond aesthetics to the greater good of emissions-free electricity.(29)

The mechanical operations of a modern wind turbine are virtually silent. Turbines generate noise, however, as the spinning blades move through the air. Proponents of wind power argue that modern turbines are designed to minimize noise pollution and that a normal conversation is possible at the base of an operating turbine. The French wind power company La Française d'Eoliennes claims that the noise level 150 metres from modern turbines

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(27) With respect to CO_2, SO_x and NO_x emissions.

(28) Sid Perkins, "Change in the Weather? Wind farms might affect local climates," *Science News*, Vol. 166, No. 16, 2004, p. 246 (http://www.sciencenews.org/articles/20041016/fob7.asp).

(29) Dawn Walton, "Alberta's Wind-power Fight Buffets David Suzuki," *The Globe and Mail* [Toronto], 29 April 2005, p. A1.

is only 50 decibels (dB), similar to the background noise in a household.(30) The Danish wind power industry claims that its current systems generate only 65 dB right at the base of the turbine. It also argues that at wind speeds of 8 metres per second or more, discussions about sound emissions from modern wind turbines may be purely theoretical since background noise (e.g., wind in leaves, masts, tall grasses) will likely mask any turbine noise.(31)

Two types of noise are generated by the turbines: ultra-low-frequency or infrasound; and audible, though typically low-frequency, sound. Because the noise is low and in some cases pulsing,(32) it may in fact be more noticeable indoors, because buildings can act as resonators for the sound and people may feel the low-frequency sound as much as they hear it.(33) There have been claims that low-frequency sound generated by wind turbines can cause mental anguish and sleep deprivation in those exposed to it for extended periods. Neither of the two reports typically cited for this argument, however, actually suggests that noise from wind power is sufficient to cause these problems. In fact, one of the authors has gone as far as to speak out publicly against the use of his findings as an argument against wind farms.(34)

While it is not certain whether noise from wind farms causes mental or physical health problems, there is evidence that both the visual and noise pollution do have an economic impact in the form of lowered property values. Estimates from Australia, the United Kingdom, and the Netherlands all suggest that property value may be decreased by 30% by the visible presence of wind turbines. In countering these arguments, wind power advocates typically cite a 2003 study published by the Renewable Energy Policy Project(35) and a second study done for

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(30) A refrigerator alone can generate 50 dB, while a quiet office or library typically has a background noise level of about 40 dB. Continued exposure to noise at 85 dB can cause hearing loss.

(31) Danish Wind Industry Association, *Sound from Wind Turbines*, Copenhagen, updated 19 September 2003 (http://www.windpower.org/en/tour/env/sound.htm).

(32) Turbines with rotors upwind of the tower virtually never create pulsing sound.

(33) Neil Kelley, "Is Low Frequency Noise a Problem for Wind Turbines?" *Wind Energy FAQ*, American Wind Energy Association, 1998 (http://www.awea.org/faq/noise-lf.html).

(34) The two reports in question are: Geoff Leventhall *et al.*, *A Review of Low Frequency Noise and its Effects*, prepared for the United Kingdom Department of the Environment, Food and Rural Affairs, London, May 2003; and Birgitta Berglund *et al.*, eds., *Guidelines for community noise*, World Health Organization, Geneva, 1999.

(35) George Sterzinger *et al.*, *The Effect of Wind Development on Local Property Values*, Renewable Energy Policy Project, Washington, 2003 (http://www.repp.org/articles/static/1/binaries/wind_online_final.pdf).

the Phoenix Economic Development Group,[(36)] both of which concluded that turbines do not reduce property values. However, it has been noted by many, including real estate associations, that these studies used analytical methods that are not acceptable for this type of evaluation.

D. Avian Injury and Mortality

There is no doubt that wind turbines kill and injure birds.[(37)] Direct causes of death are primarily contact with moving rotors, and also electrocution on contact with some system components. Indirect causes of death are habitat changes and altered avian behaviour in response to the presence of turbines. Even the strongest proponents of wind power concede that flight paths and bird habitat use must be considered when planning a new wind development. There is considerable debate, however, as to the number of birds killed and the effectiveness of various mitigation measures.

The Altamont Pass Wind Resource Area in California, with approximately 5,000 turbines, is the largest wind farm region in the world and is often cited as the prime example of wind turbines causing avian mortality. A recent study for the California Energy Commission on ways to reduce the number of bird deaths at Altamont estimates that the wind turbines kill 1,766 to 4,721 birds annually.[(38)] The same study, however, also points out that Altamont is not a suitable example of the impacts of modern wind farms on birds, because its turbines and farm design are outdated and not representative of a modern wind power facility. In particular, Altamont has a relatively large number of turbines, and their design is outdated:[(39)] they have small, rapidly rotating blades, and many are mounted on trellis towers – two factors which the industry claims cause far more bird deaths than new, larger, slower turbines on pylon-type towers. The study also blames the elevated number of bird deaths at Altamont on the poorly planned installation of turbines with respect to bird flight paths, lack of strategically placed bird

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(36) Stephen Grover, *Economic Impacts of Wind Power in Kittitas County: Final Report*, prepared for the Phoenix Economic Development Group by ECONorthwest, Portland, 2002 (http://www.econw.com/pdf/kittitas.pdf).

(37) Wind turbines are also responsible for the death of numerous bats, but fewer data are available on this topic, which will not be addressed in this paper.

(38) BioResource Consultants, *Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area*, prepared for the California Energy Commission, Public Interest Energy Research Program: Final report No. 500-04-052, September 2004.

(39) Because the turbines are older and smaller, more of them are needed to generate the same output as would modern turbines. Shorter rotors sweep a smaller area and spin much more quickly than the long blades on new turbines.

deterrents, insufficient management of prey species that are attracted by the towers, and the presence of standing but non-operational turbines.

The National Wind Coordinating Committee (NWCC), which publishes information on avian mortality related to wind power, estimated in 2001 that the 15,000 turbines operating in the United States were killing 33,000 birds a year.(40) In November 2004, the NWCC reported an estimated 3.1 bird deaths annually per MW of wind-generating capacity for the United States outside of California, with a low of 1 bird death per MW at an open agricultural site and a high of 15 per MW in a fragmented mountain forest. The NWCC information on indirect mortality is less substantive, and reflects the current limited understanding of the effects of wind farms on bird habitat and behaviour.

Data from U.S sites and Altamont Pass in particular indicate that raptors may suffer relatively greater mortality from turbines than other types of birds. It has been postulated that land disturbance, increased human activity, and additional shelter offered by the structures all act to make wind farms attractive habitat for small rodents, the main prey of most raptors identified in the mortality data. In contrast to this thinking, however, nesting boxes for birds of prey are mounted directly on the turbines in Denmark.

Most of the raptors affected in the Altamont Pass area are protected by federal legislation, as are many other species of birds affected by wind farms in the United States and Canada.(41) Often, killing even one of these birds is a violation of federal law, even if the death is accidental. It is not clear how new proposals such as the five new wind farms in Ontario will address this potential legal liability. In Canada, there is no record of the federal government taking action against a person for accidentally killing birds protected under the *Migratory Birds Act*, with the exception of hunters claiming to have accidentally shot a protected species; but in the United States, organizations have taken civil action against turbine owners and operators.(42)

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(40) Wallace P. Erickson *et al.*, *Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Others Sources of Avian Collision Mortality in the United States*, Western EcoSystems Technology Inc. for the National Wind Coordinating Committee, Washington, August 2001 (http://www.nationalwind.org/publications/avian/avian_collisions.pdf). The NWCC notes that this report has not been subjected to its consensus process.

(41) In Canada, federal protection is afforded under the *Migratory Birds Act* and the *Species at Risk Act*.

(42) For example, the Centre for Biological Diversity has filed a suit against the developer of Altamont Pass and the Danish turbine manufacturer for the facility, claiming that the wind farm kills more than 60 golden eagles, 300 red-tailed hawks and 270 western burrowing owls annually. All of these species are federally protected in the United States and Canada.

E. Land Use

Wind farms, as the name implies, are expansive. In a 2004 National Center for Policy Analysis (NCPA) comparison of the "footprints" of various power generation facilities, wind power was estimated to require nearly 78 hectares (ha) per megawatt, while nuclear and coal required respectively about 0.7 and 0.8 hectares per megawatt.(43) These numbers, however, may be on the high side. The Summerview wind power facility in Alberta will have a capacity of 130 MW when completed and use 2,023 hectares of land (15.6 ha/MW). A proposed facility for Reids Corners in Ontario will have a capacity of 75 MW and occupy 1,659 hectares of land (22.1 ha/MW). Ontario Power Generation's coal-burning Lambton Generating Station can produce 1,975 MW on 445 hectares (0.2 ha/MW). The energy-per-hectare rating of all three of these sites is roughly four times better than the NCPA estimates.

Wind power advocates do not deny that their systems require large areas of land (or sea), but counter that the actual space used by each individual tower is minimal and the space in between towers is still available for other uses. In this way, wind farms lend themselves to mixed land use, especially in agricultural settings, since the typical open expanses of agricultural areas often also provide a good wind resource.(44) It is possible to cultivate crops or graze livestock around the individual turbines: in western Canada, cattle graze in pastures dotted with turbines for which the land-rental fees ensure a stable and predictable income to the farm owner. In addition, CanWEA and other industry groups claim that wind farms can also be integrated into industrial settings.

The expansive nature of wind farms requires extensive infrastructure to support the collection, control and distribution of generated power. In some cases the infrastructure, such as roads, power lines, and outbuildings, may have a greater environmental impact than the operation of the turbines. The extent of the environmental impact of such infrastructure depends largely on the nature of the site prior to its disruption. For example, opening up remote forests to mechanized access can cause major soil loss, habitat fragmentation, and changes in ecosystem functions. The presence of roads and structures such as utility poles and buildings with windows also increases the incidents of collisions with birds and animals. The installation of roads, power lines, substations, and outbuildings in an active agricultural area may cause similar problems, though probably to a lesser degree.

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(43) H. Sterling Burnett, *Wind Power: Red Not Green*, Brief Analysis No. 467, National Center for Policy Analysis, Dallas, 2004 (http://www.ncpa.org/pub/ba/ba467/).

(44) The North America map from Archer and Jacobson (2005) shows that the best non-coastal wind resources are found in the U.S. midwest and the Canadian prairies.

CONCLUSION: NAVIGATING TURBULENT WINDS

It is clear that with respect to atmospheric emissions and the renewable nature of the resource, wind power has many strengths. It can help in the fight against global warming, smog- and mercury-related health issues, and emissions-related environmental concerns. Furthermore, increased alternative energy production reduces dependence on non-renewable fossil fuels. Diversity in energy production creates resilience in the electricity network, and economic and social benefits in terms of a diverse workforce. This being said, concerns regarding wind power's potential to cause noise and visual pollution as well as avian mortality are legitimate. Furthermore, wind power in North America currently requires government subsidies in order to be economically competitive.

The world's current dependence on traditional sources of electricity is untenable, and a shift away from it is necessary and inevitable. The global demand for oil is increasing while worldwide production will probably peak sometime in the next two decades, driving prices upward. Humanity's consumption of electricity and all forms of energy continues to grow, and the fuels for many of the traditional forms of generation are limited. This situation, along with growing acceptance that human-induced climate change is real and that carbon dioxide emissions are a major contributing factor, will increase incentives to develop non-carbon-based sources of power. Wind power will have an important role to play in this new energy mix. However, careful, objective consideration of its pros and cons will be necessary in order to determine wind power's contribution to this new energy regime.