Journal for Nature Conservation **16** (2008) 44—55

Available online at www.sciencedirect.com

ScienceDirect

Journal for Nature Conservation

www.elsevier.de/jnc

Adverse impacts of wind power generation on collision behaviour of birds and anti-predator behaviour of squirrels

Ryunosuke Kikuchi*

Departamento de Ciências Exactas e do Ambiente (CERNAS), ESAC – Instituto Politécnico de Coimbra, Bencanta, 3040-316 Coimbra, Portugal

Received 4 December 2006; accepted 9 November 2007

KEYWORDS
Alarm call;
Bern convention;
Migration;
Mortality;
Raptors;
Renewable energy;
Wind farm

Summary

Wind power is a fast-growing energy source for electricity production, and some environmental impacts (e.g. noise and bird collision) are pointed out. Despite extensive land use (2600–6000 m^2/MW), it is said that most of these impacts have been resolved by technological development and proper site selection. The results in this paper suggest that: (i) wind farms kill millions of birds yearly around the world, and the high mortality of rare raptors is of particular concern; (ii) wind farms on migration routes are particularly dangerous, and it is difficult to find a wind power site away from migration routes because there is no guarantee that migration routes will not vary; (iii) according to the presented model of collision probability, the rotor speed does not make a significant difference in collision probability; the hub is the most dangerous part, and large birds (e.g. raptors) are at great risk; and, (iv) based on the field observation of squirrels' vocalisation (i.e. anti-predator behaviour), there are behavioural differences between squirrels at the wind turbine site and those at the control site. Noise from wind turbines (when active) may interfere with the lives of animals beneath the wind turbines.

US Government guidelines and the Bern Convention's report have described adverse impacts of wind energy facilities on wildlife and have put forward recommendations. In addition to these documents, the following points derived from the discussion in this paper should be noted for the purpose of harmonising wind power generation with wildlife conservation: (i) engineers need to develop a turbine form to reduce the collision risk at the hub; (ii) institute long-term monitoring, including a comparison between bird mortality before and after construction; and (iii) further evaluate impacts of turbine noise on anti-predator wildlife vocalisations.

*Tel.: +351 239 802287; fax: +351 239 802979.
E-mail address: kikuchi@mail.esac.pt.

1617-1381/$ - see front matter © 2008 Elsevier GmbH. All rights reserved.
doi:10.1016/j.jnc.2007.11.001

Introduction

The first wind-powered electricity was produced by a machine built by C. Brush in 1888. This machine had a rated power of 12 kW (DWIA, 2003). During the 1980s, installed capacity costs dropped considerably and since then wind power has become an economically attractive option for commercial electricity generation (ITDG, 2005). Large wind farms or wind power stations have become a common sight in many western countries; e.g. Denmark alone had 2000 MW of electricity generating capacity from more than 5700 wind turbines in 2001, representing ~15% of their national electricity consumption (ITDG, 2005). Wind energy is being adopted in more and more countries, with 58,982 MW installed worldwide in 2005 (World Wind Energy Association (WWEA), 2006).

The global rate of growth of wind power increased to 24% in 2005, up from 21% in 2004; with this trend continuing to increase, 120,000 MW is projected to be installed worldwide by 2010 (WWEA, 2006). This dynamic increase shown in Figure 1 can be justified as follows: since wind is a clean, renewable form of energy and a free source of electricity, it will reduce energy dependence on imported fossil fuel and reduce the output of greenhouse gases (e.g. CO_2) and other pollution (e.g. SO_2, NO_x, etc.). Therefore, many public organisations are promoting the construction of vast wind farms, encouraging private companies with generous subsidies and regulatory support, requiring utilities to buy from them, and setting up markets for the trade of green credits in addition to actual energy.

Wind power seems to be environment friendly. However, some considerations need to kept in mind when planning a wind power scheme. Disadvantages of wind power may hinge on the extensive land use required for wind farms, and possible demerits can be evaluated according to a multi-criteria matrix (e.g. Gamboa & Munda, 2006):

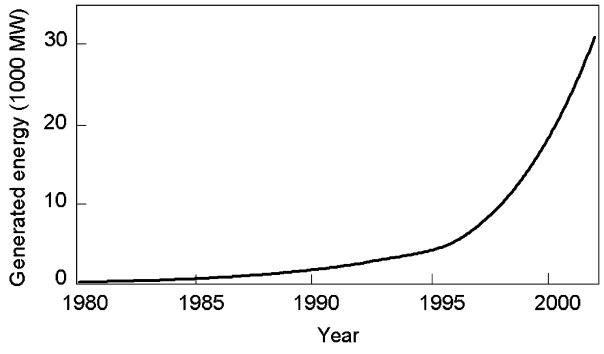

Figure 1. Worldwide energy generated by wind power (reviewed by Podolsky, 2003).

income issues, number of jobs, visual impact, forest loss, noise, CO_2 reduction and installation capacity. The evaluation criteria encompass economic, sociological, socio-ecological and technical issues, but wildlife impacts are not included. In spite of extensive land use (2600–6000 m^2/MW), wildlife impacts including noise have not been sufficiently taken into account in wind power schemes. The following reasons are reported: (i) the sounds emitted by modern wind turbines are usually masked by other natural sounds in the area (The Office of Energy Efficiency and Renewable Energy (OEERE), 2005; WRA, 2005); and (ii) current wind turbine technology offers a solid tubular tower to prevent birds from perching on it, and turbine blades rotate more slowly than those of earlier design (OEERE, 2005; WRA, 2005).

There have been few comprehensive studies and even fewer published scientific papers on wildlife impacts of wind power, and many studies suffer from a total lack of assessment of relevant factors, e.g. collision risk, differences in bird behaviour, etc. (Birdlife International, 2003). In light of the significant increase in the use of wind power (see Figure 1), it seems worthwhile to assess whether wildlife impacts from wind power generation are really negligible. This subject is discussed based on the collision behaviour of birds and the anti-predator behaviour of squirrels. The purpose of this paper is not to criticise wind power generation but to discuss relevant impact factors in great detail. The main purpose is to take a general view of the data and establish a fundamental concept in order to encourage an environment friendly relationship between wildlife and wind power generation. Therefore, the description of each topic is simple, followed by a general principle for linking strategies for nature conservation with those for renewable energy. The principles of wind power generation are outlined first, followed by the main discussion.

Principles of wind power generation

Wind power plants (or wind farms as they are sometimes called), are clusters of wind machines used to produce electricity. A wind farm usually has dozens of wind machines scattered over a large area. A simple overview of the technology for wind power generation is provided by Bockris (1977), Adachi (1997), Pereira (1998) and ITDG (2005).

Basic theory

Wind (air in motion) is a form of solar energy, that is, it is caused by the uneven heating of the