Wind Turbines and Wind Farms

This article is a 'work in progress' incorporating new information whenever time permits.

1. Introduction
2. EMF problems
3. Sound
4. Flicker and strobing
5. Positioning of wind turbines
6. Electricity distribution networks
7. Effect on animals, birds and bats
8. Wind Turbine design, costs and lifetime
9. Jobs
10. Subsidies
11. Effect on house prices
12. 21 References

Wind Turbines – Wind Farms

There are increasing numbers of wind farms being erected across the countryside to provide a more sustainable source of energy to replace our historical dependence on fossil fuels. As well as large wind farms a number of small windmills are being erected on buildings to provide a local power generation source to reduce expenditure on energy and to contribute to the overall production of more sustainable energy.

At the moment there are 252 operational turbines in the Highlands and Islands of Scotland. A further 278 are under construction or approved, while 1,130 are being considered. 150 of these are planned near Loch Ness, and hundreds of turbines within 5 kilometres of the coastline.

The Scottish government has a target to generate 100% of electricity from renewables by 2020. 2,800MW of wind capacity is installed across Scotland, with a further 3,400MW in planning. A further 4,000MW is at an earlier stage in the process. Onshore and offshore wind projects will be the biggest contributor to meeting the Scottish government's targets but biomass, hydro and later wave and tidal will also have an input.

Scotland is already ahead of England, which has just 950MW of operational wind-generated power, Northern Ireland has 387MW and Wales has 413MW. The rest of the UK also has many fewer wind turbines in planning.

It is possibly the smaller population levels of Scotland that enable the wind turbines to be built away from centres of population, reducing the symptoms experienced by local residents. Some of the more vocal complainants are those hoping to exploit tourism for their own purposes, by building very expensive resorts, the view from which will be 'spoilt' by such structures.

Discussed below are the different concerns that have been raised, and at the bottom a more general evaluation of wind turbine energy production. The figures available are for a large wind farm, rather than isolated small windmills.

As always, nothing is simple and straightforward. The major reported problems are the sound (especially extremely low frequency -"infra"- sound from the turbines, which not everybody can hear, but is very troublesome to those who can, as well as the aesthetic question. Some people seem more accepting of the visual appearance than others. A study by Pedersen & Persson Waye (2007) concluded *"There is a need to take the unique environment into account when planning a new wind farm so that adverse health effects are avoided."* They stated that perception and annoyance were greater in rural rather than suburban settings, and that complex ground (hilly or rocky terrain) increased the risk of perception and annoyance than flat ground.

3 modern large wind farms in Russia were looked at with regard to environmental issues. It was shown that in the process of wind farm construction, soil and ground water contamination could take place due to the working of construction equipment and vehicle, excavation, welding and other operations. During the operation of the wind turbines there could be elevated levels of acoustic and electromagnetic pollution in the neighbourhood and emergencies with the destruction of equipment in adverse weather conditions. The authors (Kireeva 2013) recommended distances of 700 metres from the outermost wind turbines to avoid noise problems and 200 metres from residences to protect people from possible emergency situations in adverse weather conditions.

There are also concerns with regard to the efficiency and longevity of the turbines and infrastructure.

In addition, there is the thorny issue regarding individual small turbines and the way they feed electricity into the grid. The Grid has not been developed to accept small *ad hoc* inputs. The problems with electricity supply are likely to grow as these new sources are added in a random fashion to the national system.

EMF problems

Are there any EMF problems associated with wind turbines?

Dr Hugo Schooneveld of the Dutch EHS foundation measured the magnetic fields from a turbine *in situ*. To his surprise, at a distance of a few metres and against the steel wall of the bases only a few nanotesla AC field could be detected. At 10 metres no field could be measured at all. He came to the conclusion that the electric circuits had been well-designed, and that no EMF dangers were to be expected from the machines. McCallum (2014) also found low levels of EMFs around wind turbines, and the associated cabling dropped to background levels of 0.04 µT at the nearest houses just over 500 metres away.

However, a Russian article (Kireeva 2009) suggests precaution due to possible risk factors from windmill electric generating plants. The authors recommend a 400 metre control area, on the basis of calculated acoustic and electromagnetic pollution possibilities.

Professor Magda Havas from Trent University in Canada, says that wind turbines generate dirty power as the electricity is converted from DC to AC and this can get onto wires coming into people's homes.

Sound

Low frequency sound vibrations (including ultrasound) generated by the rotors can make people feel ill. Dr Nina Pierpont (MD, PhD), a New York paediatrician, has coined the term "Wind Turbine Syndrome", also known as vibroacoustic disease (VAD). She has provided expert testimony before the New York State Legislature Energy Committee. She recommends that wind turbines should not be built any closer than 2,000 metres to housing.

Dr Pierpont's research claims that any or all of the following symptoms can occur as the result of a person living too closely to a wind turbine.

- Sleep problems: noise or physical sensations of pulsation or pressure make it hard to go to sleep and cause frequent awakening (Hanning & Evans 2012).
- Tachycardia
- Headaches which are increased in frequency or severity.
- Visual blurring
- Dizziness, unsteadiness, and nausea.
- Exhaustion, anxiety, panic attacks, anger, irritability, and depression.
- Problems with concentration and learning.
- Tinnitus (ringing in the ears).

According to Pierpont, eight of the 10 families in her study moved out of their homes.

In a review of studies, Baliatsas (2016) found there were some associations between exposure to low frequency noise (LFN) and annoyance, sleep-related problems, concentration difficulties and headache in the adult population living in the vicinity of a range of LFN sources.

Klæboe & Sundfør (2016) found that pulsating swishing sounds and turbine engine hum are the main causes of noise annoyance in a small Norwegian community near a windmill park.

Professor Mariana Alves-Pereira (an acoustical engineer) and Dr Nuno Castelo Branco (a surgical pathologist) have taken numerous noise/vibration measurements within a Portuguese home surrounded by 4 industrial wind turbines. The closest turbine is nearly 300 metres from the affected home. Their report concluded: *"These results irrefutably demonstrate that windmills in the proximity of residential areas produce acoustical environments that can lead to the development of VAD in the nearby home-dwellers."*

British physician Amanda Harry, in a February 2007 article titled *Wind Turbines, Noise and Health*, wrote of 39 people, including residents of New Zealand and Australia, who suffered from the sounds emitted by wind turbines.

This article by Harry, Frey & Hadden (2007) concluded that a safe buffer zone of at least 2 kilometres should exist between family dwellings and industrial wind turbines of up to 2MW installed capacity, with greater separation for a wind turbine greater than 2MW installed capacity.

The report said that the health responses in those living nearby included sleep deprivation, headaches, migraines, nausea, dizziness, palpitations, tinnitus, stress, anxiety and depression. These symptoms had a knock-on effect in the residents' daily lives, causing poor concentration, irritability and an inability to cope. The injuries were considered in the context of human rights, where it is contended that the environmental noise pollution destroys a person's effective enjoyment of right to respect for home and private life, a violation of Article 8 of the European Court of Human Rights Act.

An investigation by the Ddass (Direction Départementale des Affaires Sanitaires et Sociales) found sound levels occasionally exceeded allowable limits at 1 kilometre away.

The UK government guidelines on acceptable noise levels for wind turbines have not been changed substantially since 1997 and there has been little sign that changes in wind turbine technology is reflected in these guidelines. This guidance was designed for structures of about 27 metres in height, but some applications for wind farms include turbines that are at least 3 times higher.

Consultants recommended lowering night-time noise limits because the sounds made by spinning blades were enough to disrupt sleep patterns. However, the advice given to the government in a draft 2006 report was removed from the final submission. This means that hundreds of turbines at wind farms in Britain built since 2006 have been allowed to continue generating high levels of noise (Telegraph 2009).

Knopper (2014) suggested that audible noise from wind turbines can be annoying to some, who report health effects (e.g., sleep disturbance) especially at sound pressure levels of more than 40 dB(A). Because environmental noise above certain levels is a recognized factor in a number of health issues, siting restrictions have been implemented in many jurisdictions to limit noise exposure.

In a study by Baliatsas (2016b), 722 responded "absolutely agree" to the statement "I am sensitive to noise". People in this group reported high scores on number and duration of self-reported non-specific symptoms (NSS), increased psychological distress, decreased sleep quality and general health, more negative symptom perceptions and higher prevalence of healthcare contacts, GP-registered NSS and prescriptions for antidepressants and benzodiazepines.

In a review by Kubo (2017), the authors concluded that there were significant associations between the noises or annoyance produced by wind turbines and subjective adverse health effects reported. However, there was insufficient evidence to conclude whether the annoyance was caused by the psychological response to the construction of wind farms or by the actual exposure to noises generated by wind farms.

In Canada, Jalali (2016) made a study using self-reported general health and health-related quality of life (QOL) of people living in proximity to wind turbines (WTs). The scores significantly worsened after the WTs began operation for those participants who had a negative attitude to WTs, who voiced concerns about property devaluation, and/or who reported being annoyed visually or by the noise. In a second study, Jalali (2016b) reported that residents living near WTs reported poorer sleep quality if they had a negative attitude to WTs, if they had concerns related to property devaluation, and if they could see turbines from their properties.

There are clearly individual differences and psychological factors in reports of sleep disturbance by people living in the vicinity of WTs, and Blanes-Vidal & Schwartz (2016) suggested that symptoms are likely to be due to confounding bias.

Noise is difficult to measure as microphone wind noise can corrupt outdoor recordings; it is almost inevitable because measurements cannot be made in still conditions (Kendrick 2016).

Flicker and Strobing

There are two distinct types of flicker associated with wind turbines. Shadow flicker arises as the shadow of the moving turbine blades moves across the ground. This type of flicker is most common when the sun is at a low angle in the sky, such as mornings and evenings in the summer and just about any time in the winter. The second type of flicker that can arise from wind turbines is strobing. Strobing occurs when turbine blades catch the sun and reflect it back towards the viewer. Since a turbine blade will be in the position where this reflection takes place up to 60 times per minute, the effect is like a strobe light. Strobing can occur at any time of day and can happen anywhere the turbines can be seen – especially from the south, east and west. Small windmills situated on top of buildings have created a strobe effect as the sun was seen behind the revolving blades.

The most severe, though by no means the only, health risk associated with shadow flicker and strobing is seizure. Other risks include headache, loss of balance, nausea and disorientation. Variables associated with wind turbine shadow flicker included, but were not limited to, annoyance to other wind turbine-related features, concern for physical safety, and noise sensitivity (Voicescu 2016).

Nina Pierpoint said *"Dizziness (specifically vertigo) and anxiety are neurologically linked phenomena. Hence the anxiety and depression seen in association with other symptoms near wind installations are not a neurotic response to symptoms, but rather a neurologically linked response to the balance disturbances people experience from shadow flicker or low-frequency noise. Those living within ½ mile should be apprised that they are likely to experience very bothersome levels of noise and flicker, which continue (though to a lesser degree) to a mile or more from the turbines."*

Positioning of wind turbines

The power available from the wind is a function of the *cube* of the wind speed. Therefore if the wind blows at twice the speed, its energy content will increase eight fold. In practice, turbines at a site where the wind speed averages eight metres per second will produce around 80% more electricity than those where the average wind speed is six metres per second.

A study looking at an atmospheric general circulation estimates that only comparatively few land areas are suitable to generate more than 1 W_e m^{-2} of electricity and that larger deployment scales are likely to reduce the expected electricity generation rate of each turbine (Miller & Kleidon 2016). The authors conclude that these atmospheric effects are relevant for planning the future expansion of wind power.

The Ministry of Defence have objected to the positioning of certain wind turbines as they interfere with primary and secondary radar, and with low flying. Tracking aircraft flying over a wind farm is extremely difficult.

Electricity distribution networks

The government said that £4.7bn should be spent on the National grid in order to transport the green energy needed to help meet the UK's target to produce 15% of the UK's energy from renewables by 2020. The campaign groups say this will mean transmitting energy through some of the country's most protected landscapes as much of the wind energy will be generated in remote areas of Scotland or off the coast of Wales. As well as Snowdonia, four designated areas of outstanding natural beauty, in Anglesey, Kent, Lincolnshire and Somerset would be affected by the new lines (BBC News March 2009).

"The Lewis Wind Farm Proposal HIA which was completed by public health specialists in Scotland, does look at the wider determinants of health and specifically refers to the issue of power cables and EMFs. Its recommendations for the developer to follow included that the cables be as far away as possible from residential dwellings, certainly not less than 100m.

Effect on animals, birds and bats

Badgers living less than 1 kilometre from a wind farm had a high cortisol level and are physiologically stressed (Agnew 2016). They did not become habituated to the turbine disturbance 3 years later and still had high levels.

Łopucki (2017) found that reactions of animals were species specific. Herbivorous mammals (roe deer and European hare) avoided wind farm interiors and proximity to turbines. The common pheasant showed a positive reaction to wind turbine proximity. The red fox had the most neutral response to wind turbines.

Meanwhile, researchers at the University of Aberdeen (Nicholls & Racey 2009) found that directing a radar beam at **bat** foraging sites reduced the number of bats colliding with turbine blades, as the sound of the radar disturbs them and the heat can make them uncomfortable so they avoid it. It is unclear whether this is only usable in areas where the MoD do not fly. It may also add to environmental RF problems for those sensitive to radar transmissions.

The impacts of mortality associated with intensive wind-energy development may affect bat species dissimilarly, with red bats potentially better able to absorb sustained mortality than hoary bats because of their larger effective size (N_e) (Pylant 2016). Wind turbine mortality of the Indian bat interacted with white-nose syndrome and together these stressors had a larger impact than would be expected from either alone, principally because these stressors together act to reduce species abundance across the spectrum of population sizes (Erickson 2016).

2 dead **bats** have been found at Braes of Doune, Stirlingshire. One had broken bones from a possible collision with a turbine blade, but the other had no obvious signs of impact. One of the concerns is that the blades turn so fast the bats can't detect them and another is a change in pressure which is believed to damage the bats internally.

In a study by Rosin (2016) the results demonstrated a constant negative relationship between wind turbine proximity and **bird** numbers. Other environmental variables, such as field size, proximity of settlements and water bodies that also had constant associations with bird populations across seasons may be taken into account when minimizing adverse effects of wind farm development on birds or choosing optimal locations of new turbines.

There was a negative effect of the immediate vicinity of a wind turbine on the stress parameters of **geese** and their productivity. They gained less weight, had a higher concentration of cortisol in blood and had disturbed changes in behaviour (Mikolajczak 2013).

The anticipated 5,000 wind turbines planned for the German Bight in the future will provide new artificial reef habitats for another 320% crabs (C. pagurus) and 50% wrasse (Ctenolabrus rupestris) representing substrata-limited mobile demersal hard bottom species (Krone 2017).

Wind Turbine design, costs and lifetime

Some of the information below is taken from sources which are promoting the development of wind farms and this should be borne in mind.

Wind turbine design has improved so that modern ones are designed to work for some 120,000 hours of operation throughout their design lifetime of 20 years. http://www.windpower.org/en/tour/econ/oandm.htm. Danish experience shows that maintenance costs are generally very low while the turbines are brand new, but they increase somewhat as the turbine ages. The actual lifetime of a wind turbine depends both on the quality of the turbine and the local climatic conditions, e.g. the amount of turbulence at the site

According to http://www.bwea.com/ref/econ.html, the wind turbine structure represents 64% of the cost of the project. The balance of the cost comes from civil works, electrical infrastructure, grid connection, etc. Onshore wind energy is competitive with new coal fired plant, and cheaper than new nuclear power.

http://www.woodlawnwind.com.au/_PDF/_Sections/19.pdf A Danish paper *The Energy Balance of Modern Wind Turbines* (Wind Power 1997) records the results of a detailed calculation of the energy balance, based on energy use associated with manufacture, installation, operations and decommissioning of a 600 kW Danish turbine.

A 2006 summary of all the reports and studies to date was compiled by Cutler Cleveland at Boston University. Cleveland's analysis was posted on the Oil Drum October 19, 2006.

Cleveland found that the average Energy Return on Investment (EROI)for wind turbines of the studies he evaluated varied depending upon whether the study assumed how the wind turbine would perform or whether it used actual field experience. For studies that estimated performance, the average EROI was 24.6, for those that used field experience the average EROI was 18.1. If wind turbines can be expected to operate for 20 years, then the average energy payback for those studies estimating performance is 9.8 months, for those studies using field experience the average energy payback is 13 months. While substantially longer than the paybacks determined by the early studies cited here, Cleveland's work confirms that wind turbines typically pay for their energy content within the first year of operation.

There are a variety of good primary sources with claims of energy balance being achieved after 13 months. 13 months is the point at which balance is achieved for the measured data as opposed to the estimated data which is unsurprisingly lower.
See http://www.theoildrum.com/story/2006/10/17/18478/085#more

The results can be summarised as follows:

- The turbine would recover all the energy spent in its manufacture, maintenance and decommissioning/disposal after about 13 months of its commissioning. This figure is based on measured, rather than theoretical results many of which quote shorter periods of time

- With a standard 20-year design lifetime, the wind turbine would supply at least 80 times the energy spent in its manufacture, installation, operation, maintenance and decommissioning/disposal
- The decommissioning of the turbine would require energy, but recycling would "save" slightly more energy in being able to recycle most materials, especially metals, than the energy required for the disposal process. Landfilling is the most cost-effective disposal method in the United States, but it imposes significant environmental impacts. Thermal, mechanical, and chemical processes allow for some energy and/or material recovery, but they also carry potential negative externalities (Ramirez-Tejeda 2017). The authors argue for the necessity of policy intervention that encourages industry to develop better technologies to make wind turbine blade disposal sustainable, both environmentally and economically.

It looks as if the overall energy payback period has been decreasing from a few years to one year more or less for land-based windfarms. Sea-based ones will have significantly longer energy balance periods.

Jobs

Cabinet Minister Ed Davey told the Telegraph in March 2012 that living next to a wind farm is good for you. There are a lot of wind farms that are being put up yo the benefit of local communities, he adds.

Onshore wind farms are bringing jobs to the Highlands, with up to 5,000 jobs in the industry already across Scotland.

The infrastructure created for onshore wind projects will also help bring new technologies on-stream like wave and tidal projects.

Subsidies

The current subsidies are expected to fall as wind technology becomes more efficient. At the moment, Ed Davey, Secretary of State for Energy and Climate Change, says that using public money to support wind technology will increase employment and exports.

Effect on house prices

In a study by Sims & Dent (2007) they suggested that the impact of wind farms on house prices was more noticeable for terraced (54% lower in value) and semi-detached houses (35% lower) with there being a significant impact on properties located within a mile of a wind farm. The effect seems to be much less marked, if at all, for detached houses. There seemed to be other issues involved in the Cornish sites that were investigated that made the issue unclear, such as open-cast mining sites and Ministry of defence housing that were considered to have impacted on property values. Houses at the more expensive end of the range of prices (which are more likely to be detached houses) were also excluded, thus making the conclusion about the value of detached houses being unaffected seem less secure.

The Telegraph online 14 July 2013 lists the top ten things that devalue your home. Windfarms are at number 4: "Data released last year by the Valuation Office Agency reveals a number of home owners have successfully applied to have their properties placed in a lower council band because of their proximity to a wind farm. Hard evidence is difficult to come by, but one couple in Devon saw the value of their property reduced from £400,000 to £300,000."

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