Extract from WIND TURBINE NOISE, SLEEP AND HEALTH, April 2010

Dr Christopher Hanning. BSc, MB, BS, MRCS, LRCP, FRCA, MD

Notes:
This paper is based on proofs of evidence produced for several UK Planning Inquiries. As such, it concentrates on the regulatory system in the UK. Other jurisdictions will have different systems.
The aim is to inform those seeking to regulate the siting of wind turbines close to human habitation.
It will be updated regularly as new information comes to hand.
Users are encouraged to check the Society for Wind Vigilance Website for the latest updates
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Summary

Section 1 sets out the author's expertise in sleep medicine and physiology, the scope of the report and source material.

Section 2 reviews the basic physiology of sleep. Noise can disturb sleep by causing awakenings, which are remembered and arousals, which are not recalled but are more likely. Both disrupt sleep making it unrefreshing. Research on the effects of wind turbine noise has concentrated on remembered awakenings and has thus underestimated the effects.
Inadequate or poor quality sleep has many health consequences apart from daytime sleepiness and fatigue. These include obesity, poor memory, increased risk of diabetes, heart disease and high blood pressure. Vulnerable groups such as children and the elderly may be at greater risk.

Section 3 reviews research on wind turbine noise, sleep disturbance and health. These include the major contributions of van den Berg and Pedersen and the dose-response relationship derived from their data. Also considered are the Salford study and the Hayes McKenzie Partnership study commissioned by the DTI.
Recent major reports by WHO (the World Health Organisation) and RIVM (the National Institute for Public Health and the Environment in Holland) are reviewed, both of which mandate lower night time noise levels than are permitted by ETSU-R-97. Predicted external turbine noise should not exceed 35dB to avoid disturbance to sleep and 40dB to avoid risks to health. Experience of existing wind farms mandates a setback of at least 1.5km in order to avoid disturbance to sleep.
It is concluded that there is compelling evidence that wind turbine noise can and does disturb sleep and impair the health of those living too close and that current guidance is inadequate protection.

Section 4 examines the mitigation of wind turbine noise. It is concluded that the occupants of properties sited within 1.5km of turbines will suffer unacceptable levels of sleep disturbance and potential risk to their health.

Section 5 presents the conclusions of the report.

Section 6 lists the documents cited in support of this paper.
Figure 1. Sound level and annoyance for different noise sources
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1. Introduction

1.1 The author

1.1.1. My name is Dr Christopher Hanning, Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, based at Leicester General Hospital, having retired in September 2007 as Consultant in Sleep Disorders Medicine. In 1969, I obtained a First class Honours BSc in Physiology and, in 1972, qualified in medicine, MB, BS, MRCS, LRCP from St Bartholomew's

Hospital Medical School. After initial training in anaesthesia, I became a Fellow of the Royal College of Anaesthetists by examination in 1976 and was awarded a doctorate from the University of Leicester in 1996. I was appointed Senior Lecturer in Anaesthesia and Honorary Consultant Anaesthetist to Leicester General Hospital in 1981. In 1996, I was appointed Consultant Anaesthetist with a special interest in Sleep Medicine to Leicester General Hospital and Honorary Senior Lecturer to the University of Leicester.

1.1.2. My interest in sleep and its disorders began nearly 30 years ago and has grown ever since. I founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the country, until retirement. The University Hospitals of Leicester NHS Trust named the Sleep Laboratory after me as a mark of its esteem. I was a founder member and President of the British Sleep Society and its honorary secretary for four years and have written and lectured extensively on sleep and its disorders and continue to be involved in research. My expertise in this field has been accepted by the civil, criminal and family courts. I chair the Advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly, and sit on Advisory panels for several companies with interests in sleep medicine. I am an Associate Member of the General Medical Council, chairing Investigation Committee hearings and Registration Panels.

4.2. Mitigation of wind turbine noise

4.2.1. Bowdler (2008) has recently reviewed the causation of the swishing and thumping noises associated with wind turbines. He concludes that, while there are several theories, no definitive mechanism can be established. It follows that industry claims to mitigate turbine noise by changing blade shape, pitch and turbine spacing should be treated with scepticism until definitive evidence of their efficacy are presented.

4.2.2. It follows that attempts to reduce wind turbine noise immissions after a plant becomes operational are unlikely to be successful. Noise mitigation will reduce power output, which will be opposed by the operators. The importance of assuring residents that noise limits are capable of being met before construction was emphasised by Mr Lavender, Inspector at the Thackson's Well Inquiry (APP/E2530/A/08/2073384) who stated: *"securing compliance with noise limit controls at wind farms, in the event of a breach, is not as straightforward as with most other forms of noise generating development. This is because noise from turbines is affected primarily by external factors such as topography and wind strength, a characteristic that distinguishes them from many other sources of noise, such as internal combustion engines or amplified music, which can be more directly and immediately influenced by silencing equipment, insulation or operator control."* It follows that application of the precautionary principle is essential where there is any possibility of noise disturbance from wind turbines.

4.2.3. Thus, the **only** mitigation for wind turbine noise is to place a sufficient distance between the turbines and places of human habitation. PPS22 advises that ETSU-R-97 *should* (author's italics) be used to estimate noise levels around turbines which, taken with measurements of ambient noise, can, in theory, predict noise disturbance in adjacent properties. Many expert acousticians have severely criticised ETSU-R-97, not least Mr Dick Bowdler (2007), a former member of the Government's Noise Working Group considering ETSU-R-97. A number of Her Majesty's Inspectors have been equally critical, not least Mr Andrew Pykett (Appeal

ref:APP/Q1153/A/06/2017162) and Ms Elizabeth Ord (APP/W4705/A/09/2114165). As noted above, the recent recommendation by some members of the Noise Working Group to provide more allowance for wind shear in predicting turbine noise levels is a tacit admission of the unsuitability of ETSU-R-97 methodology for large turbines. In addition the suppressed recommendations by HMP, at least one of whose employees sat on the NWG, for a reduction in the ETSU-R-97 night time noise limits to 33-38dB(A) suggests very strongly that it is inappropriate to continue to rely on ETSU-R-97 as presently formulated.

4.2.4. Stigwood (2008) has shown that large turbines (hub heights 50-100m) are more likely than smaller turbines (hub height 30m) to cause excessive amplitude modulation, increased likelihood of low frequency noise and greater disturbance inside buildings. Internal noise can modulate over 15-20dB, changes which are easily perceived. This is probably due to different wind speeds and atmospheric conditions at these heights. He concludes that ETSU-R-97, which was developed for smaller turbines, is inappropriate for large turbines.

4.2.5. Despite, or because of, ETSU-R-97, complaints of noise disturbance from industrial wind turbines continue and it is clear that ETSU-R-97 can not be relied upon to prevent sleep disturbance in those living near wind turbines. To quote Mr Peter Hadden in evidence to the House of Lords Economic Affairs Committee, printed 12th November 2008 para 6: *"There is material evidence available to show that ETSU R 97 has failed to provide a reasonable level of protection to family homes from unbearable noise pollution where wind turbines are located too close to homes. Symptoms include sleep disturbances and deprivation, sometimes so severe that families are forced to evacuate their homes in order to stabilise well-being and to resume normal family life. This is a worldwide phenomenon where wind turbines are located too close to homes."*

4.2.6. It should be noted also that the application of ETSU-R-97 is advisory in PPS22, not mandatory (*should* not *must*). It is subordinate also to the precautionary principle set out in PPS 22. Rather than rely on a provably inadequate set of theoretical calculations to determine setback distance, it is logical to look at the real world and the relationship between setback and noise complaints from existing sites. Human senses and opinion are used to judge visual impact. It is therefore consistent and logical to rely on human senses and opinion in respect of noise impact. Many of these sites causing problems have been in place for several years. Current applications are for large 2.0-3.0MW turbines and thus allowance must be made for their additional noise in determining setback.

4.2.7. While it may be possible to produce a reasonable acoustically based theoretical approach to calculating set-back distances (Kamperman and James 2008b), it makes more sense to rely on recommendations from observations of the effects on real people at established wind farms and the dose-response relationship described by Pedersen (2009a&b) is relevant.

4.2.8. New Zealand Standard 6808, cited in draft form above, has been published recently (March 2010). It permits a turbine noise level of 40dB $L_{A90(10min)}$ or 5dB above background, whichever is the greater. In areas where a higher degree of acoustic protection is warranted, the evening and night-time level may be set at 35dB $L_{A90(10min)}$ or 5dB above background, whichever is the greater. Wind speeds are referenced to hub height.

4.3. Conclusions

4.3.1. There are two possible approaches to judging an appropriate setback distance. The first is to determine a dose-response relationship between turbine noise and a health concern, for example, sleep disturbance. The next step is to determine an acceptable level of sleep disturbance. For example, should it be 0%, 1% or 5% of the population for 1 night per year, per month or per week? Consideration should be given to whether the measured concern, in this case reported sleep disturbance, is sufficiently sensitive. I have shown that reported sleep disturbance is the tip of an iceberg and that arousals with sleep fragmentation are likely to be more common and insidious with consequences including fatigue and elevated blood pressure In this situation, it would be appropriate to invoke the precautionary principle and select a conservative dose level (turbine noise) that minimises the measured response (sleep disturbance). Examination of data from the Swedish and Dutch studies suggests that an external predicted noise level of no more than 35dB(A) would be appropriate. This view is supported by a presentation by members of RIVM, the widely respected Dutch National Institute for Public Health and Environment, (Jabben et al 2009) which recommends an outdoor L_{den} limit of 40dB(A) which corresponds to an external noise level of about 35dB(A). The data is now available as a RIVM report (Verheijen et al. 2009) which recommends that wind turbine parks be designed so as to stay below L_{den} 40 dB at nearby dwellings which is regarded as the "no effect" level. L_{den} 45 dB(A) is recommended as a maximum allowable limit which should avoid severe effects and minimise health effects. Hayes (2007) notes that "the intent of New Zealand Standard 6808 is not inaudibility but the prevention of severe annoyance". The relevant section of that Standard states:

"***4.4.2 Acceptable limit:*** *As a guide to the limits of acceptability, the sound level from the WTG (or windfarm) should not exceed, at any residential site, and at any of the nominated wind speeds, the background sound level (L_{95}) by more than 5dB(A), or a level of 40 dB(A) L_{95}, whichever is the greater.*

Hayes therefore concedes that the noise level above which severe annoyance occurs is 40dB(A). Thorne (2010), from an analysis of noise complaints concludes that unreasonable noise occurs at noise levels above 30dB(A)$_{LA90}$ in the presence of excess amplitude modulation. Together with van den Berg he states: "*We believe annoyance and loss of amenity will be protected when the wind turbine noise limit would be 30 dBA L_{95} in conditions of low wind speed at the dwellings and modulation restricted to 3dB"*.

Overall, it is apparent that the present ETSU-R-97 noise limits are too high to protect receptors from severe annoyance and sleep disturbance and that a level of 35dB(A) is appropriate, in the absence of excessive modulation.

4.3.2. The second approach is to correlate reports from those living in proximity to wind turbines to their distance to the turbines, the approach taken by, amongst others, WindVOiCe (Wind Vigilance for Ontario Communities). This has the disadvantage that symptoms are generally self-reported and subjective. Nevertheless, it can be argued that it is logical to rely on the actual reports of human receptors in the same way that human opinions are used to judge visual amenity. It has the advantage also that it may better detect those subjects that are most sensitive to turbine noise than surveys. It has the merit also of simplicity. The New South Wales Legislative Council General Purpose Standing Committee No 5, under the Chairmanship of Mr Ian Cohen, a member of the Green Party, has recently published the report of an inquiry into rural wind farms (NSW 2009).

Recommendation 7 to the NSW Planning Minister is for a minimum setback of 2 km. In the UK, Mr Peter Luff, MP for Mid-Worcestershire, introduced a Bill to Parliament to establish a legal minimum setback distance.
4.3.3. **Table II** (see end of text) shows recommendations for setback distance by a number of authorities. References can be found in the Bibliography. In general, noise engineers recommend lesser setback distances than physicians. The former rely more on measured and/or calculated sound pressures and the latter on clinical reports. It is logical to prefer the actual reports of the humans subjected to the noise rather than abstract calculations, even if the latter accurately measure ambient noise and allow for the low frequency components of wind turbine noise. Calculations can not measure annoyance and sleep disturbance, only humans can do so. **In my opinion, based on the reports cited in the table and the data from the WindVOiCe survey, a minimum setback of 1.5km is appropriate.**
4.35. **Turbines which result in external noise levels greater than 35dB(A) or are sited closer than 1.5km from housing therefore present an unacceptable risk of causing sleep disturbance and high levels of annoyance to those residents and, to a smaller number, a risk to health.**

5. Planning considerations

5.1 ETSU-R-97

5.1.1. UKGovernment policy is that ETSU-R-97 should be used for the assessment of the likely impact of wind turbine noise and this was restated in a 2007 policy statement. Developers will often assert that, as it is government policy, ETSU-R-97 may not be questioned. However, as Mr Justice Mitting stated in a judicial review brought by the Renewable Energy Foundation: “It will always be open to any objector to an application for permission to develop a site as a windfarm, to contend that the Statement is technically inadequate or erroneous.” David Forsdick, of Landmark Chambers, a leading barrister with particular expertise in planning matters, stated, at a seminar on renewable energy on the 1st October 2008 (Forsdick 2008): *“...., general policy and guidance cannot prevent consideration of: a. the specific facts of an individual case; b. scientific information which suggests that the general methodology may need to be adjusted on the facts of an individual case; or c. actual experience elsewhere on the ground which shows that the government approved methodology does not always accurately predict the impacts.*
Thus, whilst it is undoubtedly true that it is not for parties to an inquiry to question the merits of government policy, their evidence on the matters in the previous paragraph is plainly capable of constituting “other material considerations” which the decision maker has to take into account and, in an appropriate case, reach a conclusion on.
5.1.2 It would seem logical that the specific facts of an individual case would include the presence of particularly sensitive or vulnerable receptors, such as the elderly and children, and the likelihood of excessive wind shear or amplitude modulation.
5.1.3. There is now a large body of scientific information showing that the ETSU-R-97 methodology is in need of adjustment for wind shear and excess amplitude modulation.
5.1.4. There is a large body of evidence also showing that ETSU-R-97 noise levels are too high for human health and well being. These include the 2009 WHO Night Noise Guidelines and the 2006 draft reports by HMP to DTI.
5.1.5. It follows that it is appropriate and reasonable for planners and decision makers not to rely exclusively on ETSU-R-97 methodology and to take account of the other material considerations set out in this paper.

6. Overall Conclusions

6.1. The appropriate mitigation of sleep disturbance and annoyance from industrial wind turbine noise is a maximum external turbine noise level of 35dB(A) or a setback of at least 1.5km.

CD Hanning

8th April 2010