Report by

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on

# Sleep disturbance and wind turbine noise

on behalf of

Against Wind Farm at Low Spinney **(AWFALS)**

in respect of an

Application by Broadview Energy Developments Ltd

Harborough District Council ref: 09/00174/FUL

Proposed Construction of 4 Wind Turbines
each of up to 3 MW max capacity
and maximum dimensions of:
80m towers, 45m blades or 125m overall (410ft)

at Low Spinney

August 2009

# Contents

# EXECUTIVE SUMMARY

This report reviews the evidence for an effect on wind turbine noise on health and sleep disturbance in particular.

It concludes that the proposed development at Low Spinney is likely to cause unacceptable levels of annoyance and sleep disturbance to the residents of Ashby Magna, Gilmorton, Dunton Bassett and surrounding properties and must be rejected.

The significance of this prediction rests on peer-reviewed research results that conclude sleep disturbance can lead to adverse health outcomes.

# KEY POINTS

The following points are based on clear, proper, documentary evidence:

Wind turbine noise is audible and annoying to a large proportion of residents at distances of up to 2km and, in some cases, beyond and is more audible and annoying at night. It is more annoying than equivalent traffic noise and is not fully masked by traffic noise

Complaints of fatigue, poor concentration and memory, headache and nausea (wind turbine syndrome) are made by residents living up to 2km and more from existing wind turbines, most of which are smaller than those proposed by Broadview

Adequate restorative sleep is essential for human health and well being. Wind turbine noise can prevent the onset of sleep and the return to sleep after an awakening. Wind turbine noise can cause awakenings from sleep and, almost certainly, arousals leading to fragmented sleep and is a likely cause of wind turbine syndrome

The recommended assessment tool for wind turbine noise (ETSU-R-97) is fundamentally flawed and considerably underestimates noise and annoyance. Recent peer –reviewed studies recommend much lower external turbine noise levels than are permitted by ETSU-R-97. ETSU-R-97 must be disregarded to protect the health of local residents.

The only mitigation of wind turbine noise is an adequate distance between turbines and homes (setback). Setbacks of at least 1.5km are recommended by the majority of authorities who have examined the human effects of wind turbine noise. These distances correspond with the newest recommended noise limits.

The majority of Ashby Magna, Gilmorton, Dunton Bassett and adjacent farms and residencies are within 1.5km of the proposed turbines. This is too close for the continuing health and well being of the residents to be assured. All properties subject to noise monitoring will have external turbine noise levels greater than those recommended by the latest research.

This application is contrary to the following policies

- **PPS22 –** as the site is within 1.5km of three villages, and sleep disturbance is shown to occur within that radius, the environmental and social impacts of the development have not been minimised to an acceptable level
- **PPS7.15 –** Proposals which site wind turbines where sleep disturbance is a likely consequence cannot be said to enhance the quality of the countryside nor have regard to the amenity of local residents
- **RSS8 -** Proposals where sleep disturbance is a likely consequence do not give sufficient consideration to the noise effects on the built environment

The proposal must be **rejected** on grounds of noise, health and amenity

# 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.

1.1.3. I live in Ashby Magna, Leicestershire.

### 1.2. Brief from AWFALS

1.2.1. My brief from AWFALS was to review the potential consequences of wind turbine noise and, in particular, its effect on sleep and health and to make recommendations with regard to the proposed setback distances.

### 1.3. Scope of report.

1.3.1. This report centres on the effects of industrial wind turbine noise on sleep as this is the particular area of expertise of the author. Other areas of health concern related to low frequency noise emissions and vibro-acoustic disease will be left to others.

### 1.4. Source material

1.4.1. A full list of the publications cited and other source material is given in Section 7 and are cited in the text. Material was obtained by searching the Web of Science database using the search terms “Noise”, “Sleep” and “Wind turbine”, internet searches using the same words and scrutiny of the reference lists of published articles and reviews. Where several articles come to the same conclusion, only the most recent may be cited, in the interests of brevity. As far as possible, articles published in peer reviewed journals are cited. However, it is inevitable that some of the material is available only on the internet reflecting the paucity of government sponsored research, particularly in the UK.

## 2. Background

### 2.1. Introduction

2.1.1. There can be no reasonable doubt that industrial wind turbines whether singly or in groups (“wind farms”) generate sufficient noise to disturb the sleep and impair the health of those living nearby. Section 5.1.1 of the draft New Zealand standard on wind farm noise, 2009, states: *“Limits for wind* *farm noise are required to provide protection against sleep disturbance and maintain reasonable residential amenity."* Reports from many different locations and different countries have a common set of symptoms and have been documented by Frey and Hadden (2007). New cases are documented regularly on the Internet. The symptoms include sleep disturbance, fatigue, headaches, dizziness, nausea, changes in mood and inability to concentrate and have been named "wind turbine syndrome" by Dr Nina Pierpont (2006). The experiences of the Davis (2008) and Rashleigh (2008) families from Lincolnshire whose homes were around 900m from wind turbines make salutary reading. The noise, sleep disturbance and ill health eventually drove them from their homes. Similar stories have been reported from around the world, usually in anecdotal form but in considerable numbers.

## 2.2. Sleep, sleep physiology and the effects of noise

2.2.1. Sleep is a universal phenomenon. Every living organism contains, within its DNA, genes for a body clock which regulates an activity-inactivity cycle. In mammals, including humans, this is expressed as one or more sleep periods per 24 hours. Sleep was previously thought to be a period of withdrawal from the world designed to allow the body to recuperate and repair itself. However, modern research has shown that sleep is primarily by the brain and for the brain. The major purpose of sleep seems to be the proper laying down and storage of memories, hence the need for adequate sleep in children to facilitate learning and the poor memory and cognitive function in adults with impaired sleep from whatever cause.

2.2.2. Inadequate sleep has been associated not just with fatigue, sleepiness and cognitive impairment but also with an increased risk of obesity, impaired glucose tolerance (risk of diabetes), high blood pressure, heart disease, cancer and depression. Sleepy people have an increased risk of road traffic accidents.

2.2.3 Humans have two types of sleep, slow wave (SWS) and rapid eye movement (REM). SWS is the deep sleep which occurs early in the night while REM or dreaming sleep occurs mostly in the second half of the night. Sleep is arranged in a succession of cycles, each lasting about 90 minutes. We commonly wake between cycles, particularly between the second and third, third and fourth and fourth and fifth cycles. Awakenings are not remembered if they are less than 30 seconds in duration. As we age, awakenings become more likely and longer so we start to remember them.

2.2.4. Noise interferes with sleep in several ways. Firstly, it may be sufficiently loud or annoying to prevent the onset of sleep or the return to sleep following an awakening. It is clear also that some types of noise are more annoying than others. Constant noise is less annoying than irregular noise which varies in frequency and loudness, for example, snoring, particularly if accompanied by the snorts of sleep apnoea (breath holding). The swishing or thumping impulsive noise associated with wind turbines seems to be particularly annoying as the frequency and loudness varies with changes in wind speed and local atmospheric conditions. While there is no doubt of the occurrence of these noises and their audibility over long distances, up to 3-4km in some reports, the actual cause has not yet been fully elucidated (Bowdler 2008). Despite recommendations by the Government's own Noise Working Group, UK research in this area has been stopped.

2.2.5. Secondly, noise experienced during sleep may arouse or awaken the sleeper. A sufficiently loud or prolonged noise will result in full awakening which may be long enough to recall. Short awakenings are not recalled as, during the transition from sleep to wakefulness, one of the last functions to recover is memory (strictly, the transfer of information from short term to long term memory). The reverse is true for the transition from wakefulness to sleep. Thus only awakenings of longer than 20-30 seconds are subsequently recalled. Research that relies on recalled awakenings alone may therefore underestimate the effect.

2.2.6. Noise insufficient to cause awakening may cause an arousal. An arousal is brief, often only a few seconds long, with the sleeper moving from a deep level of sleep to a lighter level and back to a deeper level. Because full wakefulness is not reached, the sleeper has no memory of the event but the sleep has been disrupted just as effectively as if wakefulness had occurred. It is possible for several hundred arousals to occur each night without the sufferer being able to recall any of them. The sleep, because it is broken, is unrefreshing resulting in sleepiness, fatigue, headaches and poor memory and concentration (Martin 1997), many of the symptoms of "wind turbine syndrome". Arousals are associated not just with an increase in brain activity but also with physiological changes, an increase in heart rate and blood pressure, which are thought to be responsible for the increase in cardiovascular risk. A clear relationship between high blood pressure and aircraft noise exposure has been shown by the HYENA consortium (Haralabidis 2008, Jarup 2008) and between traffic noise and high blood pressure for adults (Barregard 2009) and, worryingly, for preschool children (Belojevic 2007). The MESA study has suggested a link between exposure to traffic and alterations in heart function (Van Hee 2009) and Selander and colleagues (2009) have suggested a link with myocardial infarction (heart attack) but neither could separate noise effects from pollution. Arousals occur naturally during sleep and increase with age (Boselli 1998) which may make the elderly more vulnerable to wind turbine noise. Arousals may be caused by sound events as low as 32 dBA and awakenings with events of 42dBA (Muzet and Miedema 2005). Arousals in SWS may trigger a parasomnia (sleep walking, night terrors etc.). Pierpont (2009 and personal communication) notes that parasomnias developed in some of the children exposed to turbine noise in her study group.

2.2.7. Arousals are caused by aircraft, railway and traffic noise. In one study of aircraft noise, arousals were four times more likely to result than awakenings (Basner 2008a) and resulted in daytime sleepiness (Basner 2008b). Freight trains are more likely to cause arousals than passenger trains, presumably because they are slower, generating more low frequency noise and taking longer to pass (Saremi 2008). The noise of wind turbines has been likened to a "passing train that never passes" which may explain why wind turbine noise is prone to cause sleep disruption. A recent study of over 18000 subjects has shown a link between exposure to traffic noise and "the risk of getting up tired and not rested in the morning (de Kluizenaar, 2009). This study, together with that of Basner (2008b) confirms that excessive noise disturbs sleep sufficiently to impair its restorative properties and adds credence to the anecdotal reports of those living near wind turbines.

2.2.8. Studies of different alarm signals have shown that arousals and awakenings occur at lower sound levels with low frequency sounds than those of higher frequency (Bruck 2009). Repeated short beeps of 400-520Hz were most intrusive, leading to arousal and awakening. Wind turbine noise often has a considerable low frequency component and has an impulsive nature which may, in part, explain its adverse effect on sleep.

2.2.9. It is often claimed that continual exposure to a noise results in habituation, i.e. one gets used to the noise. There is little research to confirm this assertion although it has been suggested that the absence of noise for those usually subjected to high levels may cause insomnia (HPA 2009 5.29). However a recent small study (Pirrera et al. 2009) looking at the effects of traffic noise on sleep efficiency suggests that habituation does not occur.

2.2.10. Sleep disturbance and impairment of the ability to return to sleep is not trivial as almost all of us can testify. In the short term, the resulting deprivation of sleep results in daytime fatigue and sleepiness, poor concentration and memory function. Accident risks increase. In the longer term, sleep deprivation is linked to depression, weight gain, diabetes, high blood pressure and heart disease. There is a very large body of literature but please see Meerlo et al., 2008, Harding and Feldman, 2008 and Hart et al., 2008 for recent work on this subject. A more general review can found on Wikipedia: http://en.wikipedia.org/wiki/Sleep_deprivation

# 3. Wind turbine noise, sleep and health

## 3.1. Introduction

3.1.1. The evidence above demonstrates that it is entirely plausible that wind turbine noise has the potential to cause arousals, sleep fragmentation and sleep deprivation. As noted above, the draft New Zealand standard on wind farm noise (2009) acknowledges that sleep disturbance is the major adverse consequence of wind turbine noise for humans.

3.1.2 Unfortunately **all** government and industry sponsored research in this area has used **reported awakenings** from sleep as an index of the effects of turbine noise and dismisses the subjective symptoms. Because most of the sleep disturbance is not recalled, this approach seriously **underestimates** the effects of wind turbine noise on sleep.

## 3.2. Early research.

3.2.1. Surveys of residents living in the vicinity of industrial wind turbines show high levels of disturbance to sleep and annoyance. A 2005 survey of 200 residents living within 1km of a 6 turbine, 9MW installation in France showed that 27% found the noise disturbing at night (Butre 2005). A similar US survey in 2001 (Kabes 2001) of a “wind farm” in Kewaunee County, Wisconsin reported that 52% of those living within 400-800 metres found the noise to be a problem, 32% of those living within 800-1600 metres and 4% of those within 1600 and 3200 metres. 67% of those living within 250 to 400 metres and 35% of those within 400-800 metres reported being awoken by the sound in the previous year. The principal health problem reported by the 223 respondents was sleep loss. The landscape of Kewaunee County is described as “undulating to gently rolling”, not dissimilar to South Leicestershire. All of these studies were of smaller turbines than proposed by Broadview. Pedersen and Waye (2004) reported that “16% (*n*=20, 95%CI: 11%–20%) of the 128 respondents living at calculated external turbine noise exposure above 35.0 dBA stated that they were disturbed in their sleep by wind turbine noise." All of these studies use reported awakenings and may therefore underestimate the effects of wind turbine noise on sleep.

3.2.2. Phipps and others (2007) surveyed 1100 New Zealand residents living up to 3.5 km from a wind farm, 604 responded. 75% of all respondents reported being able to hear the noise. Two separate developments have placed over 100 turbines with capacities from 600kW to 1.65MW in this hilly to mountainous area. It has been suggested that mountainous areas may allow low frequency noise to travel further which may explain the long distance over which the turbines were heard. Van den Berg (2004) found that residents up to 1900 m from a wind farm expressed annoyance with the noise, a finding replicated in his more recent study reported below. Dr Amanda Harry (2007), a UK GP, conducted surveys of a number of residents living near several different turbine sites and reported a similar constellation of symptoms from all sites. A study of 42 respondents showed that 81% felt their health had been affected, in 76% it was sufficiently severe to consult a doctor and 73% felt their life quality had been adversely impacted. This study is open to criticism for its design which invited symptom reporting and was not controlled. While the proportion of those affected may be questioned it nevertheless indicates strongly that some subjects are severely affected by wind turbine noise at distances thought by governments and the industry to be safe.

## 3.3. Project WINDFARMperception

3.3.1. van den Berg and colleagues (2008) from the University of Groningen in the Netherlands have recently published a major questionnaire study of residents living within 2.5km from wind turbines, Project WINDFARMperception. A random selection of 1948 residents were sent a similar questionnaire to that used by Pedersen in her studies in Sweden (2003, 2004, 2007 and 2008), questions on health, based on the validated General Heath Questionnaire (GHQ), were added. 725 (37%) replied which is good for a survey of this type but, nevertheless may be a weakness. Non-respondents were asked to complete a shortened questionnaire. Their responses did not differ from full respondents suggesting the latter are representative of the population as a whole.

Questions on wind turbine noise were interspersed with questions on other environmental factors to avoid bias. The sound level at the residents' dwellings was calculated, knowing the turbine type and distance, according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime -that is: at high, but not maximum power. Ground absorption was set to 1.0, a 100% sound absorbing surface. Typical values are around 0.5 and thus the sound levels may have been under-estimated. Noise exposure ranged between 24 and 54dBA. It is worth noting that the industry was approached for assistance in the research but refused. Complaints such as annoyance, waking from sleep, difficulty in returning to sleep and other health complaints were related to the calculated noise levels.

Relevant conclusions include. *"Sound was the most annoying aspect of wind turbines"* and was more of an annoyance at night. Interrupted sleep and difficulty in returning to sleep increased with calculated noise level as did annoyance, both indoors and outdoors. Even at the lowest noise levels, 20% of respondents reported disturbed sleep at least one night per month. At a calculated noise level of 30-35dBA, 10% were rather or very annoyed at wind turbine sound, 20% at 35-40dBA and 25% at 40-43dBA (the permitted ETSU-R-97 night time level).

3.3.2. Project WINDFARMperception further found that *"Three out of four participants declare that swishing or lashing is a correct description of the sound from wind turbines. Perhaps the character of the sound is the cause of the relatively high degree of annoyance. Another possible cause is that the sound of modern wind turbines on average does not decrease at night,* *but rather becomes louder, whereas most other sources are less noisy at night. At the highest sound levels in this study (45 decibel or higher) there is also a higher prevalence of sleep disturbance."* The lack of a control group prevents this group from making firmer conclusions about turbine noise and sleep disturbance but it is clear that as ETSU-R-97 permits an exterior night time noise level of 43dB, relying on its calculations will guarantee disturbed sleep for many of those living nearby.

3.3.3. van den Berg concluded also that, contrary to industry belief, road noise does not adequately mask turbine noise and reduce annoyance and disturbance. In addition, the authors compared their results with studies by Miedema on the annoyance from road, rail and air related noise. Wind turbine noise was several times more annoying than the other noise sources for equivalent noise levels (**Fig 1**). Similar data is given by Pedersen (2004) (**Fig 2**) – **see end of text**.

3.3.4 With regard to health it was concluded that: *"There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dBA) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or vice versa or whether both are related to another factor."* The conclusions regarding general health are not justified from the data for the reasons given below and must be disregarded.

3.3.5. Project WINDFARMperception is currently the largest study in this field but the study is not without considerable flaws. The study may be criticised for using calculated noise levels and for not having a control group (residents not living near turbines). While several of the contributors have expertise in the investigation of health matters, none has specific expertise in the physiology and pathophysiology of sleep. The purpose of the study, as its title suggested, was the public perception of wind turbines and their noise. Health questions were added but were of a very general nature. The small number of respondents suggests that any conclusions as to the apparent lack of an effect on health must be regarded as tentative.

3.3.6. The analysis of reported sleep interruption and wind turbine sound levels is flawed by the use of subjects exposed to calculated external turbine sound levels of <30dBA (p53) as the “controls”. It has been noted by several studies that calculated turbine noise is often less than measured noise and that levels as low as 30dBA can cause annoyance (Pedersen 2007). Examination of the odds ratio for different calculated sound levels (Table 7.42) shows that it increases progressively with increasing sound levels starting at 30-35dBA and becomes statistically significant for levels >45dBA. If, as is not impossible, the “control” group had its sleep disturbed by wind turbine noise then the actual effect would be considerably underestimated.

3.3.7. The major objection to the conclusions on health is that the study is grossly under-powered (insufficient subjects were studied for any degree of statistical confidence). Wind turbine syndrome, to the degree reported by Pierpont (2009), does not seem to be common even amongst those exposed to high noise levels. The study tried to detect chronic disease with the GHQ, which is a fairly crude instrument. Assuming that wind turbine syndrome affects 1% of those exposed to calculated sound levels >45dBA and that 25% of the general population suffer from chronic disease (p47) then at least 30,000 subjects would need to be studied in each group (<45dBA v >30dBA) to be able to prove a difference with 95% certainty. Even if a prevalence of wind turbine syndrome of 5% of those exposed to >45dBA is assumed, then there must be at least 1250 subjects in each group. This study therefore can not conclude that wind turbines do not cause ill health of any degree, it can not even make conclusions about severe ill health.

3.3.8. Pedersen, van den Berg and others (Pedersen 2009b) have further analysed the data in an attempt to model a generalised dose-response relationship for wind turbine noise. A noise metric, Lden, was calculated (Miedema 2000). Lden is based on long-term equivalent sound pressure levels adjusted for day (d), evening (e) and night). Penalties of 5 and 10dB are added for evening and night hours to reflect the need for quietness at those times. dBA values for wind turbines may be transformed to Lden values by adding 4.7±1.5 dB (van den Berg 2008). Annoyance is used as the principal human response to wind turbine noise in this analysis. In this context, "annoyance" is more than simply irritation but is a measure of lack of well-being in a wider sense (Pedersen 2009a) and is contrary to the WHO definition of health.

Annoyance increased with increasing sound levels, both indoors and outdoors. The proportion who were rather and very annoyed at different sound levels are shown in Table I. In summary, when outside, 18% were rather or very annoyed at sound levels of 35-40 and 40-45 dBA compared to 7% at 30-35dBA and 2% at <30dBA. When inside, the equivalent figures were 1% at <30dBA, 4% at 30-35dBA, 8% at 35-40dBA and 18% at 40-45dBA. Those respondents who had an economic interest in the turbines had lower levels of annoyance while negative views of the visual impact of turbines increased the likelihood of annoyance.

Although the authors do not seek to recommend minimum sound levels, they do note that turbine noise was more annoying than other sources, with the possible exception of railway shunting yards and was more noticeable at night. They conclude that: *"...nighttime conditions should be treated as crucial in recommendations for wind turbine noise limits."* Nevertheless, it is clear from this analysis that external predicted turbine sound levels should be less than 35dBA, considerably less than those permitted by ETSU R 97, in order to reduce effects on nearby residents to acceptable levels.

3.3.8. Pedersen (2009) has recently combined the datasets from three studies (Pedersen 2004 (SWE00)) and 2007 (SWE05) and van den Berg 2008 (NL07)) as they used similar questionnaires giving a total of 1764 subjects. A strong correlation was seen in all studies between calculated A weighted sound pressure levels and outdoor annoyance as noted above.

Even at sound pressures of 30-35 dB(A), 5-12% of subjects were very annoyed. Correlations were found also between annoyance and symptoms of stress (headache, tiredness, tension and irritability) confirming that “annoyance” is more than irritation and is a marker of impaired health. The sleep disturbance question did not ask causation of the sleep disturbance and a background level would therefore be expected from other causes (traffic noise, weather, etc). Nevertheless, there was a clear increase in levels of sleep disturbance with A-weighted sound pressure in studies SWE00 and NL005. **(Figure 3)**. Pedersen states *“In the first Swedish study (SWE00) the increase of respondents that reported sleep interruption appears to be between the sound level interval 35-40 dB(A) and 40-45 dB(A). The increase came at higher sound levels in the Dutch study (NL07); between the interval 40-45 dB(A) and >45 dB(A)”*. There is no true measurement of background levels of sleep disturbance as no study had a control group, it is difficult therefore to determine at what sound pressure level turbine noise begins to have an effect. but even the conservative levels suggested above are less than those permitted by ETSU R 97. **Fig 3 see end of text.**

3.3.9. Jabben and colleagues (2009) from the RIVM, the Dutch National Institute for Public Health and Environment, were commissioned by the Dutch Government to examine the impact of different values of Lden on the ability to meet targets for onshore wind power generation. They reviewed current evidence and noted that, at present, 440,000 inhabitants (2.5% of the population) were *“receiving significant noise contribution from wind turbine noise of which 1,500 are expected to suffer severe annoyance. It is remarkable that almost half of this number already occurs within the range Lden 30-40db(A)”.* Despite this, they recommend an Lden of no more than 40dB(A), which corresponds to a calculated external turbine noise level of about 35.3dBA, in order for the Dutch Government to meet its 2011 target for wind turbine installations.

3.3.10. All of the studies cited in this section have used reported sleep disturbance and annoyance in determining maximum sound levels. As noted in Section 2.2, reported sleep disturbances underestimate sleep disturbance and may not reflect actual physiological consequences. The precautionary principle demands that lower sound levels be selected in order to leave a margin of safety.

## 3.4. Pierpont studies

3.4.1. Pierpont (2009 and personal communication) has recently completed a very detailed, peer-reviewed case-series study of 10 families around the world who have been so affected by wind turbine noise that they have had to leave their homes, nine of them permanently. The turbines ranged from 1.5 to 3MW capacity at distances between 305 to 1500m. The group comprised 21 adults, 7 teenagers and 10 children of whom 23 were interviewed. While this is a highly selected group, the ability to examine symptoms before, during and after exposure to turbine noise gives it a strength rarely found in similar case-series studies. The subjects described the symptoms of wind turbine syndrome outlined above and confirmed that they were not present before the turbines started operation and resolved once exposure ceased. There was a clear relationship between the symptoms, even in children, and the noise exposure. She reports also that all adult subjects reported *"feeling jittery inside"* or *"internal quivering"*, often accompanied by anxiety, fearfulness, sleep disturbance and irritability. Pierpont offers compelling evidence that these symptoms are related to low frequency sound and suggests very plausible physiological mechanisms to explain the link between turbine exposure and the symptoms.

3.4.2. Of particular concern were the observed effects on children, include toddlers and school and college aged children. Changes in sleep pattern, behaviour and academic performance were noted. 7 of 10 children had a decline in their school performance while exposed to wind turbine noise which recovered after exposure ceased. In total, 20 of 34 study subjects reported problems with concentration or memory.

3.4.3. Pierpont's study mostly addresses the mechanism for the health problems associated with exposure to wind turbine noise rather than the likelihood of an individual developing symptoms. Nevertheless, it convincingly shows that **wind turbine noise is strongly associated with the symptoms of wind turbine syndrome**, including sleep disturbance. She concludes by calling for further research, particularly in children, and a 2km setback distance.

3.4.4. A recent paper (Todd et al, 2008) has shown that the vestibular system in the human ear, the part concerned with detection of movement and balance, is exquisitely sensitive to vibration at frequencies of around 100Hz. While this must be regarded as preliminary data, it does offer further evidence in support of Dr Pierpont's findings and theories.

## 3.5. DTI report

3.5.1. Broadview is likely to refer to a DTI report by the Hayes McKenzie Partnership published in 2006 which investigated low frequency noise at three UK wind farms. Hayes McKenzie have a long term relationship with the wind turbine industry, are noise engineers with no medical or physiological expertise so their suitability to undertake the work must be questioned. They took sound measurements at three of five sites where complaints had been recorded over periods from 1-2 months.

Communication with residents other than those who complained was minimal. However, they did confirm that *"some wind farms clearly result in modulation at night which is greater than that assumed with the ETSU-R-97 guidelines".* Measured *"internal noise levels were insufficient to wake up residents at these three sites. However, once awoken, this noise can result in difficulties in returning to sleep."*

The lack of physiological expertise in the investigators in not recognising that noise can disturb sleep without actual recalled awakening is a major methodological flaw rendering the conclusions unreliable, as is the short recording period. It is well recognised also that not every resident affected by a nuisance such as noise will actually register a complaint (Health Protection Agency 2009). Many will not be sufficiently literate or confident so to do and others may wish to avoid drawing attention to the problem to protect property prices. They may assume also that protest is futile, which seems to be the experience of many with wind turbine noise. Recorded complaints are thus the tip of the iceberg.

3.5.2. It will be claimed also that only 5 of 126 wind energy developments at the time of the study had attracted complaints of noise and thus the matter is trivial. This assertion is, to say the least, disingenuous. Many of the developments at that time were of small turbines set in isolated areas of the countryside, well away from habitation. In addition, as noted above, the proportion of those affected by wind turbine noise who actually complain is very small. It must be emphasised that research into wind farm noise and health issues in the UK is virtually non-existent and of poor quality. To suggest that there is “no problem” when faced with the large body of evidence presented here is perverse. The conclusion is also contradicted by Moorhouse’s study (vide infra) which showed a complaint rate of 20%.

## 3.6. Salford study

3.6.1. Broadview is likely to refer also to a report by Moorhouse and others of the University of Salford, commissioned by DEFRA into Aerodynamic Modulation of Wind Turbine Noise published in 2007. A survey was made of the local authorities responsible for wind farms in, or adjacent to, their area. 133 wind farms were identified of which 27 (20%) had attracted complaints. An attempt was made to correlate complaint logs with recorded wind speed and direction. Once again the methodology is fundamentally flawed. Complaints were solicited from local authorities and not from residents. The review was entirely theoretical with no communication with residents. The conclusions were that AM was such a minor problem that no further research was warranted.

3.6.2. The Editor of Noise Bulletin greeted the publication of the report thus:

*"`New report eases concerns over wind turbine noise' trumpets the Government press release, then saying aerodynamic modulation is `not an issue for the UK's wind farm fleet'. This conclusion is not justified based on the report, and by halting further research work without transparently monitoring the wind farms subject to complaints will inflame, not ease concern of objectors ... Only when the public can trust the Government and wind farm developers on noise issues will there be a chance that the public will accept them without a fight ..."*
(Pease J. *Noise Bulletin*, Issue 15, Aug/Sept. 2007 page 5).

3.6.3. On 2 August 2007, Dick Bowdler, an acoustician and member of the Noise Working Group which commissioned the report, resigned from the NWG. This highly unusual step was taken because, as his letter states:

*"I have read the Salford Report and the Government Statement. As a result I feel obliged to resign from the Noise Working Group.*

*The Salford Report says that the aims of this study are to ascertain the prevalence of AM from UK wind farm sites, to try to gain a better understanding of the likely cause, and to establish whether further research into AM is required. This bears little relation to what we asked for which is clearly set out in the minutes of the meeting in August 2006. We all knew then (as was recorded in the original notes of the meeting) that complaints concerning wind farm noise are currently the exception rather than the rule. The whole reason for needing the research was that `The trend for larger more sophisticated turbines could lead to an increase in noise from AM'.*
*It was not the intended purpose of the study to establish whether more research was required. We all agreed at the August 2006 meeting that such research was needed. That was precisely the outcome of the meeting. The prime purpose of what eventually became the Salford Report was to identify up to 10 potential sites which could be used to carry out objective noise measurements. The brief for the Salford report, which was never circulated to the NWG, completely ignored the NWG views.*
*Additionally, I find it entirely unacceptable that we are not to be told the names of the wind farms listed in the Salford report. So the only part of the report of any value to assist future research is inaccessible to those of us who would like to progress matters further.*
*Looking at the Government Statement it is clear that the views of the NWG (that research is needed into AM to assist the sustainable design of wind farms in the future) have never been transmitted to government and so the Statement is based on misleading information".*
(*Noise Bulletin*, Issue 15, Aug/Sept. 2007 page 5)

3.6.4. If both a leading commentator in the field and a leading member of the Government's own working group have no faith in the study then its conclusions may safely be dismissed.

3.6.5. Following a refusal by the Salford research team and the DTI to share the study's full data, the actual questionnaire response forms were finally made available after a Freedom of Information request by the Renewable Energy Foundation. The low quality of this research is evident from the poor responses from many local authorities, compounded by the questionnaire design and the phrasing of the questions. This further serves to demonstrate that current planning guidance, and in particular ETSU R 97, are inadequate at preventing noise annoyance.

## 3.7. Kamperman comments

3.7.1. George Kamperman, (2008 personal communication) a distinguished US noise engineer, is quoted in Pierpont's book as saying, *"After the first day of* *digging into the wind turbine noise impact problems in different countries, it became clear the health impact on persons living within about two miles from 'wind farms' all had similar complaints and health problems. I have never seen this type of phenomenon [in] over fifty plus years of consulting on industrial noise problems. The magnitude of the impact is far above anything I have seen before at such relatively low sound levels. I can see the devastating health impact from wind turbine noise but I can only comment on the physical noise exposure. From my viewpoint we desperately need noise exposure level criteria."* Kamperman's recommended setback of at least 1km (Kamperman & James 2008) has changed to at least 2km as a result of Dr Pierpont's evidence (Kamperman 2008 personal communication). He has recently published a more detailed set of recommendations to determine setback distances (Kamperman & James 2008b).

## 3.8. Recent Research

3.8.1 Wind Concerns Ontario (2009) have recently published the initial results of a self-reporting survey of communities affected by wind turbine noise. As of July 2009, 107 responses had been received of which 84 reported one or more health effects. 52 of the 84 (62%) reported sleep disturbance. There were no age differences between those that reported sleep disturbance (51.5 yr (19-79)) and those that did not (52.2 yr (26-86).

Those that reported sleep disturbance lived an average of 897m (360-5000)from turbines compared to 890m (350-3500) for those who did not. A slightly greater proportion of females reported sleep disturbance than males (24/43 (56%) vs 23/51 (45%)). Caution must be exercised in drawing conclusions from self reporting surveys, nevertheless, it is evident that significant numbers of individuals are reporting sleep disturbance and health issues at distances considerably greater than those currently deemed safe. All bar three of those reporting sleep disturbance live within 1500m of the turbines adding further support to a minimum setback of at least that distance

3.8.2. Bakker and colleagues (Bakker 2009) report their observations on noise problems, including sleep deprivation, associated with wind turbines at least 3km from the affected properties. The Tararua, New Zealand, turbines are sited on a ridge and the affected properties are to the east in a river valley. Noise problems persisted despite the installation of sound reducing glazing. Nocturnal seismic noise monitoring showed noise bursts lasting at least 10 seconds, associated with an easterly wind, which the authors were confident originated from the turbines. The residents confirmed that the noise recorded was identical with that which disturbed their sleep. The authors speculate that the noise was transmitted through the ground.

The importance of this report is not the mechanism for sound transmission but scientific confirmation that wind turbines can disturb sleep at distances of 3km. Previous anecdotal reports have often be dismissed as fanciful with assertions that sound transmission over such distances is impossible. While this seems, so far, to be an isolated case, it adds further evidence that much greater setbacks than those currently required are necessary to obviate sleep disturbance.

## 3.9. Conclusions

3.9.1. The quality of the research in this area is very variable. Most are surveys using self-completed questionnaires. Response rates have generally been quite good for this type of enquiry, which may reflect the public interest and concern that wind turbines generate. Nevertheless, it is inevitable that it is more likely that those who feel they have been affected will respond rather than those who have not. The questionnaires themselves have not always have been well drafted. Most do not have a control group, a separate group not exposed to turbine noise with whom to make comparisons. The studies are all post hoc, initiated after the turbines have been operating and generally in response to complaints. The lack of pre-exposure data weakens the studies but does not invalidate them totally. Many of the authors have been criticised for their presumed lack of expertise in this area. Because governments and industry have refused funding and co-operation, individuals have had to rely on their own resources in order to conduct research, which though propelled by a concern for public health, has also enforced limits on their extents. However, initial clinical investigations often rely on self-completed questionnaires in order to define, refine, and establish future research projects and they should not simply be dismissed.

3.9.2. The UK government, in acknowledging the deleterious effect of noise on human well being, have recently published two reports through the Health Protection Agency (HPA 2009) and DEFRA (Berry and Filndell, 2009). The former, which is in draft form awaiting comments, reviews the evidence for the effects of noise on health. Traffic, aircraft, railway and industrial noise is considered but, surprisingly, there is no consideration of wind turbines despite the government's plans for a major increase in size and capacity and their proposed placement in generally previously tranquil but well populated areas of countryside, such as the East Midlands. The report calls for more research, including in the areas of sleep disturbance, cardiovascular effects and children's health. They commend the use of dose-response relationships to inform planning policy. The latter report reviews dose-response relationships between noise exposure and human health and concludes that such is a useful approach worthy of further research. They commend the work of RIVM, who were extensively consulted in preparing the report.

3.9.3. The recent analyses of the WINDFARMPerception and earlier Swedish studies by Pedersen and her colleagues gives, for the first time, robust evidence that wind turbines cause sleep disturbance and impair health and that this occurs at distances previously regarded as adequate. However, it must be noted that the measures used in these studies are relatively imprecise. As noted in Section2.2, arousals due to noise are several times more likely to occur than awakenings but are as destructive to sleep quality. More precise measures such as the Brief Fatigue Inventory or direct assessment of sleep quality are needed to determine a correct dose-response relationship between turbine noise and sleep disturbance. In the meantime, the precautionary principle should prevail and setbacks determined appropriately.

3.9.4. In weighing the evidence, I find that, on the one hand there is a large number of reported cases of sleep disturbance and, in some cases, ill health, as a result of exposure to noise from wind turbines supported by an increasing number of research reports that confirm the validity of the anecdotal reports and provide a reasonable basis for the complaints. On the other, we have badly designed industry and government reports which seek to show that there is no problem. I find the latter unconvincing.

3.9.5. **In my expert opinion, from my knowledge of sleep physiology and a review of the available research, I have no doubt that wind turbine noise emissions have been clearly associated with sleep disturbances in most of the early epidemiological studies and may well be proven in time.**

**In the future, given this early evidence, more sophisticated epidemiological studies will advance our understanding of wind turbine noise and its effects on sleep and health. Further, the evidence now available is quite clear that present noise guidelines are inadequate.**

# 4. Preventing sleep disturbance from wind turbine noise.

## 4.1 Background

4.1.1. Developers of noisy industrial processes, including wind turbines, seek to mitigate the disturbance by siting them in areas of high ambient noise, such as close to major roads. In the case of wind turbines, it is assumed that rising wind speed will not only increase turbine noise but ambient noise also. This depends on the proximity of vegetation. Motorway noise diminishes at night as the volume of traffic decreases. In addition, it is common for wind speeds to diminish at ground level as night falls while being maintained at turbine hub level, wind shear (Pedersen E and Persson Waye K. 2003, Schneider 2007). In both cases, the turbine noise will be much more audible as ambient noise decreases and explains why complaints of nocturnal noise and disturbed sleep are common. The importance of wind shear has been acknowledged in a recent technical contribution to Acoustics Bulletin (March/April 2009) from some members of the NWG calling for all noise levels to be referenced to wind speed at turbine hub height. Temperature inversion, where ground level air is cooler than higher level air also increases sound propagation by reflection of the noise from the boundary layer (Irvine. 2009). These conditions, which are most likely to occur at night, early morning and in winter have not received as much attention as wind shear but may be a further reason why turbine noise may be heard over greater distances than predicted.

4.1.2. Schneider found that night time turbine noise was between 3 and 7dBA greater than predicted and, during periods of atmospheric stability, turbine noise was 18.9 to 22.6dBA above ambient. In addition, as noted above, the characteristics of wind turbine noise are such that it can be heard despite road noise.

4.1.3. van den Berg, in a paper presented at Euronoise 2003, investigated the relationship between calculated noise generated by wind turbines and that actually measured. He confirmed that the turbines were more audible at night principally due to amplitude modulation. To quote his paper: *"As measured immission levels near the wind park Rhede show, the discrepancy may be very large: sound levels are up to 15 dB (!) higher than expected at 400 m from the wind park. At a distance of 1500 m actual sound levels are 18 dB higher than expected, 15 dB of this because of the higher sound emission and 3 dB because sound attenuation is less than predicted by the sound propagation model."* An 18dB increase is equivalent to an **8 fold increase** in sound pressure and a 15dB change is a **6 fold increase**. An 18dB increase is close to a three fold increase in perceived loudness. From this study, it would appear that calculated measures of wind turbine noise are woefully inadequate.

4.1.4. In contrast, Bullmore and colleagues (2009) reported, from studies of four established large wind farms, that ISO 9613 predicted turbine noise immissions with reasonable accuracy and, at three of the sites, over estimated the measured sound levels.

4.1.5. Bolin (2009) has reported an experimental study of the masking of wind turbine noise by vegetation noise (leaves rustling etc). Subjects were exposed to vegetation noise in a laboratory and turbine noise introduced at varying sound pressures and vice versa and a threshold for detection determined. The results were compared with the Moore and Glasberg methods for calculating masking. The results suggest that: *"....existing models of partial masking overestimate the ability to conceal wind turbine noise in ambient sounds."* In other words, wind turbine noise is not masked as well as current models predict and is thus more intrusive. This is in accord with the work of van den Berg and Miedema who show that traffic noise does not mask wind turbine noise as well as predicted.

## 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 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 (Bullmore 2009). 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 member of the Government's Noise Working Group considering ETSU-R-97.

4.2.4. Stigwood (2009) 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:

*"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. Planners should note also that the application of ETSU-R-97 is advisory in PPS22, not mandatory (*should* not *must*). It is also subordinate to the precautionary principle set out in PPS 23 (see below). 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. The application by Broadview is for larger turbines than have been previously erected in the UK 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 (2009) is relevant..

## 4.3. Ashby Magna, Gilmorton and Dunton Bassett

4.3.1. The prevailing wind in South Leicestershire is from the Southwest and the village of Ashby Magna in particular and, to a lesser extent, Dunton Bassett will be down wind of the proposed turbines and Gilmorton upwind. Under these conditions, the motorway, which is to the west of Gilmorton and Ashby Magna is most audible. Nevertheless, it is clear that there are many periods where ambient noise is low. However, for about 20% of the year, the wind is from the north east. As a resident of Ashby Magna, personal experience shows that motorway noise varies greatly, not just with wind direction but also with traffic density. With the wind from the North to Northeast, Gilmorton will now be down wind of the turbines. However, the background noise in the village diminishes markedly under these conditions as the M1 is now down wind also. The varying wind direction is confirmed in Fig 3.2 of the ES but no attempt is made to correlate wind direction with ambient noise.

4.3.2 The topography of the area is that the land falls away gently from Low Spinney towards all three villages. Reports from other wind farms suggests that these are ideal conditions for wind shear and propagation of noise over greater distances than predicted. Stable wind conditions with increased wind shear is equally likely to occur in any wind direction.

4.3.3. Under the conditions of a north easterly wind and stable wind conditions, the residents of the village of Gilmorton, which is only 800-1000 meters from the proposed turbines, will be at much greater risk of sleep disturbance from lower than average background noise levels and greater than predicted turbine noise levels.

4.3.4. Broadview’s Environmental statement 12.5.2 assumes the use of the REpower MM92 2.0MW turbine. As this is at the lowest end of the stated capacity range of 2-3MW which may be installed there must be a real doubt as to whether this represents a 'worst case scenario' or is a realistic choice for the Noise assessment.

4.3.5. Broadview's Environmental Statement details measurements and calculations made for six properties sited between 485 and 875 metres from the nearest turbines. Quiet daytime and night-time background noise levels ($LA_{90,\ 10min}$) ranged from 22.7-66.8 and 21-66.7 dBA respectively (Table 12.2). Predicted quiet daytime turbine noise exceeded 35dBA at all locations and all wind speeds except property 1 at 5 $m.s^{-1}$ and at all locations and all wind speeds at night (Tables 12.3 and 12.4). Predicted quiet daytime turbine noise exceeded 40dBA at 5 of 6 properties for most wind speeds over 5 $m.s^{-1}$ and all wind speeds over 7 $m.s^{-1}$ . Night-time predicted levels exceeded 40dBA at 3 properties at all wind speeds and at 5 properties at wind speeds over 5 $m.s^{-1}$. These calculations were performed without taking into account the recent recommendations of some members of the Noise Working Group (Acoustics Bulletin March/April 2009 pp35-37) and should be adjusted. The expectation is that an upward adjustment in predicted noise will result. For these properties at least, there is robust evidence that the occupants will be at an unacceptable risk of sleep disturbance and annoyance.

## 4.4. Conclusions

4.4.1. 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 35dBA 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 40dBA which corresponds to an external noise level of about 35dBA.

4.4.2. 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, Wind Concern Ontario. 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.

4.4.3. **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 Wind Concern Ontario, a minimum setback of 1.5km is appropriate.**

4.4.4. The proposed Low Spinney wind farm does not satisfy either of the criteria given above. Nocturnal predicted turbine sound levels exceed 35 dBA at all properties tested and most of the villages of Ashby Magna, Gilmorton and Dunton Bassett are within 1.5km. **The turbines therefore present an unacceptable risk of causing sleep disturbance and high levels of annoyance to the residents and must be rejected.**

# 5. Planning considerations

## 5.1. PPS22

5.1.1. PPS22 was promulgated subsequent to ETSU-R-97 and should therefore take precedence. Section 41 states: *"Development proposals should demonstrate any environmental, economic and social benefits as well as how any environmental and social impacts have been minimised through careful consideration of location, scale, design and other measures."* and *"Local planning authorities should ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels."*

5.1.2. Proposals that seek to place turbines where high levels of annoyance and sleep disturbance are likely consequences have not sought to minimise the environmental and social impact of wind turbine noise and its effects on sleep and health. They are therefore in contravention of PPS22.

5.1.3. The Companion Guide to PPS22 states *"RE 3 describes Factors to be considered in Planning for Wind Farms. These include: residential amenity (on noise and visual grounds); safe separation distances;"* and *"Well-specified and well-designed wind farms should be located so that increases in ambient noise levels around noise-sensitive developments are kept to acceptable levels with relation to existing background noise."*

5.1.4. Proposals that site wind turbines where high levels of annoyance and sleep disturbance are likely consequences will not keep wind turbine noise to an acceptable level and are therefore in contravention of PPS22.

## 5.2. PPS7

5.2.1. PPS7 states:

5.2.2. *“ensuring people have decent places to live by improving the quality and sustainability of local environments and neighbourhoods”*

5.2.3. *“All development in rural areas should be well designed and inclusive, in keeping and scale with its location, and sensitive to the character of the countryside and local distinctiveness”*

5.2.4. *“have regard to the amenity of any nearby residents or other rural businesses that may be adversely affected by new types of on-farm development”*

5.2.5. Section 15 states: *“Planning authorities should continue to ensure that the quality and character of the wider countryside is protected and, where possible, enhanced.”*

5.2.6. Proposals which site wind turbines where high levels of annoyance and sleep disturbance are likely consequences can not be said to enhance the quality of the countryside nor have regard to the amenity of local residents, particularly with regard to noise and must be rejected.

## 5.3. PPS23

5.3.1. PPS23 states:

5.3.2. *“the precautionary principle should be invoked when:*

- *there is good reason to believe that harmful effects may occur to human, animal or plant health, or to the environment*

- *the level of scientific uncertainty about the consequences or likelihood of the risk is such that best available scientific advice cannot assess the risk with sufficient confidence to inform decision-making."*

5.3.3. Application of ETSU R 97 is subordinate to the commitment to the Precautionary Principle outlined in PPS23**.** Good reason has been demonstrated that harmful effects may occur to human health and the precautionary principle should be invoked. The objections to ETSU R 97 are so fundamental and the concerns regarding its validity so great, as is the evidence of human harm, that the precautionary principle must be invoked and consequently PPS 23 and EV/23 applied and permission refused on that account.

## 5.4 East Midlands Regional Spatial Strategy (RSS8)

5.4.1. Policy 41 states: *"In establishing criteria for onshore wind energy Development Plans and future Local Development Frameworks, should give particular consideration to: the effect on the built environment (including noise intrusion)."*

5.4.2. Proposals where high levels of annoyance and sleep disturbance are likely consequences do not give sufficient consideration to the noise effects on the built environment and are therefore in contravention of RSS8.

## 5.5. Harborough District Local Plan

5.5.1. Harborough District Local Plan states that:

5.5.2. "*the district council will grant planning permission for the development of renewable energy schemes provided that they do not have an unacceptable impact on the landscape, features of historic and archaeological interest, nearby land use, residential amenity……..*"

5.5.3. "*..proposals should not adversely affect the established character of the surrounding area in terms of scale, space around buildings, density, design, colour and texture of materials"*

5.5.4. *"…new development should not adversely affect the amenities of neighbouring users…"*

5.5.5. Policy EV/5 states: *"The district council will refuse planning permission for development proposals in the countryside unless the following criteria are met:*

- *The development does not adversely affect the character and appearance of the countryside*
- *The development does not adversely affect the amenities of the residents of the area*
- *Any new buildings are sited in a position that minimises their impact on the landscape and on important views into and out of villages"*

5.5.6. Clearly, any development where high levels of annoyance and sleep disturbance are likely consequences will adversely affect the amenity of the residents, particularly with regard to noise, and must be rejected.

5.5.7. Policy EV/23 states: *"the District Council will impose conditions on planning permissions to ensure that the development does not have an adverse effect on the character of its surroundings or harm the amenities of nearby users, through noise…If the District Council is not satisfied that these adverse effects would be overcome by the imposition of conditions, planning permission will not be granted"*

5.5.8. The evidence presented in this paper provides incontrovertible proof that wind turbines emit levels of noise which are highly annoying and potentially harmful to human health and well-being. ETSU R 97 does not provide sufficient protection for residents, as has been amply demonstrated by several leading researchers. Planning permission must be refused.

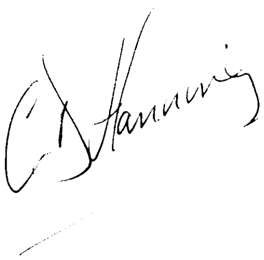
### 5.6 Leicestershire, Leicester and Rutland Structure Plan 1996-2016 Resource Management Policy 1

5.6.1. LLRSP 1996-2016 states: *"All new development will minimise or avoid air, noise, water, land and light pollution"*

5.6.2. Developments where high levels of annoyance and sleep disturbance are likely consequences will certainly not have minimised or avoided noise pollution.

## 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 35dBA or a setback of at least 1.5km. The predicted external night-time turbine noise levels at the tested properties exceed 35dBA at all wind speeds. Most of the villages of Ashby Magna and Gilmorton as well as outlying properties are within 1-1.5km of the proposed site and there is therefore a very high risk that a significant proportion of residents would be adversely affected. **The application must be rejected.**.



**CD Hanning**

**26th August 2009**

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**Figure 1. Sound level and annoyance for different noise sources** (van den Berg 2008)

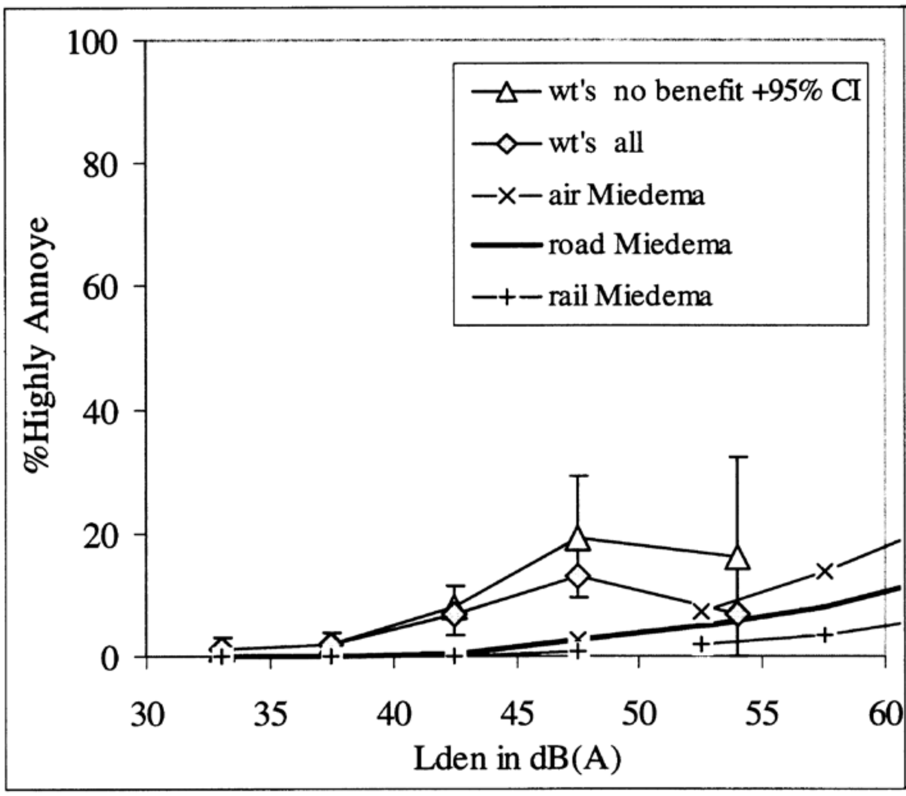
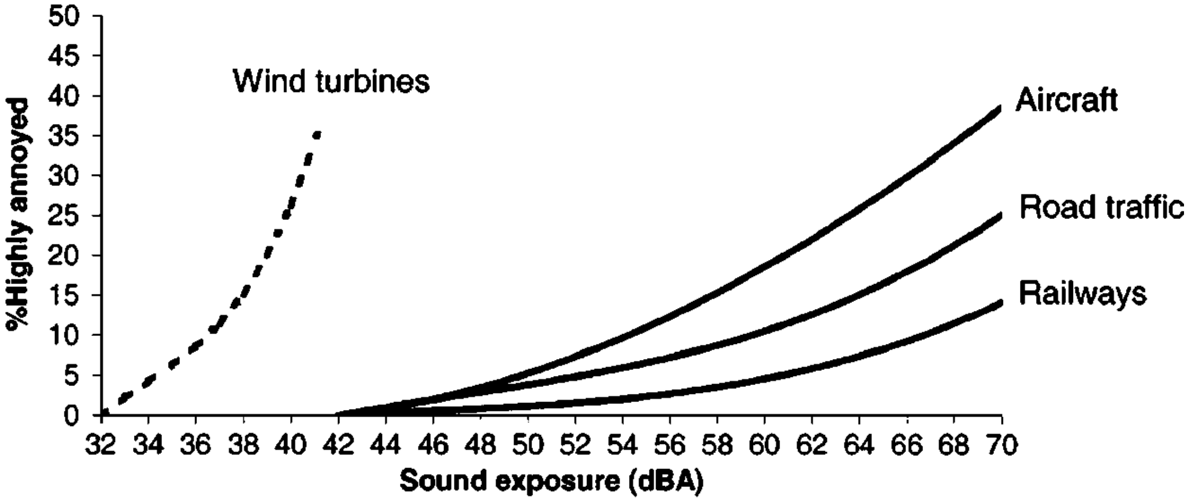



*Figure 8.1: relation between sound level Lden and percentage highly annoyed residents exposed to that sound, for three transportation noise sources and for wind turbines; the relation is given for all respondents and for those that have no economical benefit from a wind turbine.*

*Bars denote 95% confidence interval for non-benefitters.*

**Figure 2. Sound level and annoyance for different noise sources** (Pedersen E and Persson Waye, 2004)




Sound exposure is for wind turbines calculated A-weighted $L_{eq}$ for a hypothetical time period and for transportation DNL.

**Figure 3.** Relationship between A-weighted sound pressure levels (equivalent levels at wind speed 8 m/s, 10 m over the ground) and proportion of respondents disturbed in the sleep by noise in three studies: SWE00 (*n* = 341), SWE05 (*n* = 746) and NL07 (only respondents that did not benefit economically from wind turbines; *n* = 593). (Pedersen 2009)

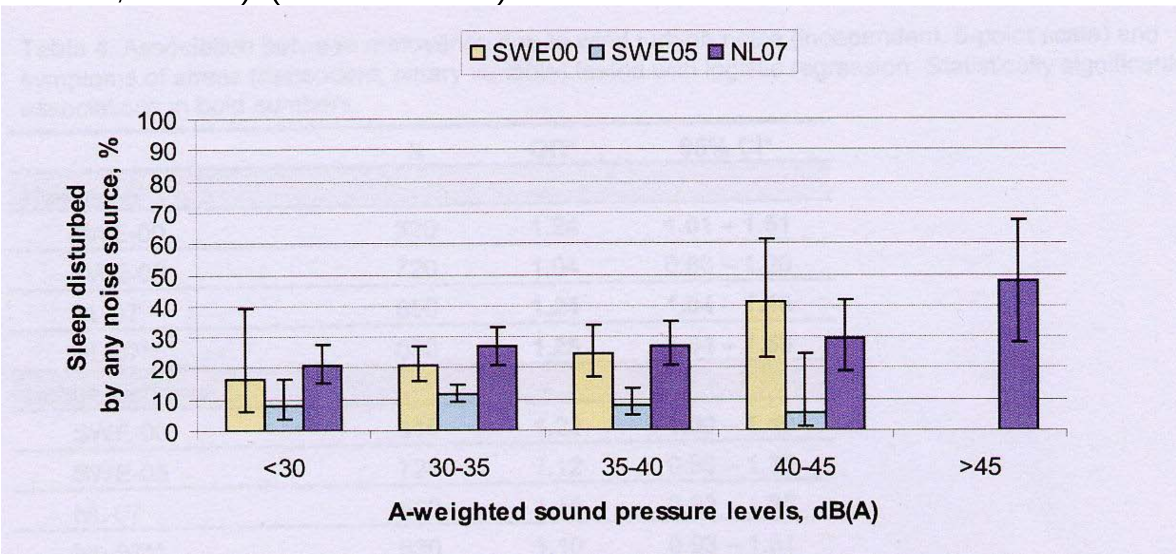


**Table I. Response to wind turbine noise outdoors or indoors, proportion of respondents (*n*=708) according to 5-dB(A) sound level intervals, and 95% confidence intervals (95%CI). (From Pedersen 2009a)**

| | Predicted *A*-weighted sound pressure levels dB(A) | | | | |
|---|---|---|---|---|---|
| | <30 | 30–35 | 35–40 | 40–45 | >45 |
| Outdoors *n* | 178 | 213 | 159 | 93 | 65 |
| Do not notice (%) (95%CI) | 75 (68–81) | 46(40–53) | 21(16–28) | 13 (8–21) | 8(3–17) |
| Notice, but not annoyed (%) (95%CI) | 20 (15–27) | 36(30–43) | 41(34–49) | 46 (36–56) | 58(46–70) |
| Slightly annoyed (%) (95%CI) | 2 (1–6) | 10(7–15) | 20 (15–27) | 23 (15–32) | 22(13–33) |
| Rather annoyed (%) (95%CI) | 1 (0–4) | 6(4–10) | 12 (8–18) | 6 (3–13) | 6(2–15) |
| Very annoyed (%) (95%CI) | 1 (0–4) | 1(0–4) | 6 (3–10) | 12 (7–20) | 6(2–15) |
| Indoors, *n* | 178 | 203 | 159 | 94 | 65 |
| Do not notice (%) (95%CI) | 87 (81–91) | 73(67–79) | 61(53–68) | 37 (28–47) | 46(35–58) |
| Notice, but not annoyed (%) (95%CI) | 11(7–17) | 15(11–20) | 22 (16–29) | 31(22–31) | 38(28–51) |
| Slightly annoyed (%) (95%CI) | 1 (0–4) | 8(5–12) | 9 (6–15) | 16 (10–25) | 9(4–19) |
| Rather annoyed (%) (95%CI) | 0 (0–2) | 3(1–6) | 4 (2–8) | 6 (3–13) | 5(2–13) |
| Very annoyed (%) (95%CI) | 1 (0–4) | 1(0–4) | 4 (2–8) | 10 (5–17) | 2(0–8) |

**Table II. Recommendations for setback of residential properties from industrial wind turbines**

Note 1. The 2km limit from edges of towns and villages seems to have been set more for visual than noise reasons
Note 2. Dixsaut and colleagues (2009) report a review of this recommendation by AFSSET. They concluded that the 1.5km setback was “not relevant” and would compromise wind park development.

| Authority | Year | Notes | Recommendation | |
|---|---|---|---|---|
| | | | Miles | Kilometres |
| Frey & Hadden | 2007 | Scientists. Turbines >2MW | >1.24 | >2 |
| Frey & Hadden | 2007 | Scientists. Turbines <2MW | 1.24 | 2 |
| Harry | 2007 | UK Physician | 1.5 | 2.4 |
| Pierpont | 2008 | US Physician | 1.5 | 2.4 |
| Welsh Affairs Select Committee | 1994 | Recommendation for smaller turbines | 0.93 | 1.5 |
| Scottish Executive | 2007 | See note 1. | 1.24 | 2 |
| Adams | 2008 | US Lawyer | 1.55 | 2.5 |
| Bowdler | 2007 | UK Noise engineer | 1.24 | 2 |
| French National Academy of Medicine | 2006 | French physicians See note 2 | 0.93 | 1.5 |
| The Noise Association | 2006 | UK scientists | 1 | 1.6 |
| Kamperman & James | 2008 | US Noise engineers | >.62 | >1 |
| Kamperman | 2008 | US Noise engineer | >1.24 | >2 |
| Bennett | 2008 | NZ Scientist | >0.93 | >1.5 |
| Acoustic Ecology Institute | 2009 | US Noise engineers | 0.93 | 1.5 |