Torfichen Wind Farm

Technical Appendix 12.2

Issues Scoped Out

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Contents

1 Introduction

This Technical Appendix provides a literature review of relevant research, issues and topics often raised by objector groups in relation to operational noise from wind turbines including low frequency noise (LFN); infrasound; sleep disturbance; vibration, aerodynamic or amplitude modulation (AM); wind turbine syndrome and perceived health effects. These topics are scoped out of any formal or detailed assessment within **Chapter 12: Acoustic Assessment** of the Environmental Impact Assessment Report on the various bases set-out below.

2 Low Frequency Noise

The frequency range of 'audible noise' is generally taken to be 20 Hz to 20 kHz, with the greatest sensitivity to sound typically in the central 500 Hz to 4,000 Hz region. The range from 10 Hz to 200 Hz is generally used to describe 'low frequency noise' (LFN) and noise with frequencies below 20 Hz used to describe 'infrasound' [1]. Although, there is sometimes a lack of consistency regarding the definition of these terms in both common usage and relevant literature in general.

LFN is always present, even in areas where 'quiet' ambient and background noise levels exist [1], and is generated by natural sources, including the sea, earthquakes, the rumble of thunder and wind. Additionally, many artificial sources found in modern life, such as household appliances (i.e. washing machines and dishwashers) and all forms of transport emit varying levels of LFN.

The noise generated by the operation of wind turbines covers a broad spectrum from low to high frequencies. The dominant frequency range of the broadband noise produced by wind turbines is not the low frequency or infrasonic ranges in terms of human perception [2]. The reason for this is that the perception threshold for hearing in these ranges is much higher than for speech frequencies of between 250 Hz and 4000 Hz. As a result of this decreased sensitivity, wind turbine noise at the lowest frequencies of the range described as LFN would typically be below the average hearing threshold.

A comprehensive literature review of 'Low Frequency Noise and Infrasound Associated with Wind Turbine Generator Systems' [2], undertaken for the

Ontario Ministry for the Environment in 2010, indicated that low frequency noise from wind turbines crosses the threshold boundary, and thus would be considered to become audible, above frequencies of around 40-50 Hz. The degree of audibility depends upon the wind conditions, the degree of masking from background noise sources and the distance from the wind turbines.

Although audible under some conditions, a paper; 'Infrasound and low frequency noise from wind turbines: exposure and health effects' [3], published by the authors of a literature review on the subject prepared for the Swedish Environmental Protection Agency in 2011 [4], concludes that the level of low frequency noise produced by wind turbines does not exceed levels from other common sources, such as road traffic noise.

In response to an article published in the national press in 2004, alleging that low frequency noise from wind turbines may give rise to adverse health effects, the Department of Trade and Industry (DTI) commissioned Hayes McKenzie Partnership to perform an independent study to investigate these claims [5]. The Government released a statement saying that *"The report concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines*", based on the findings of the report [6].

This finding is re-iterated in the review undertaken for the Ontario Ministry for the Environment [2], which concludes from publications by medical professionals that; at typical setback distances the noise levels produced by wind turbines, including noise at low and infrasound frequencies, do not represent a direct health risk.

The Oregon Health Authority's Public Health Division conducted a strategic Health Impact Assessment in response to questions regarding the potential health impacts from wind energy facilities in Oregon. The report [7] states that '*Some field studies have found that in some locations near wind turbine facilities, low frequency noise (frequencies between 10 and 200 Hz) may be near or at levels that can be heard by humans. However, there is insufficient evidence to determine if low frequency noise from wind turbines is associated with increased annoyance, disturbance or other health effects*'.

The low frequency content of the noise generated by the proposed turbines will be considered via the use of octave band specific noise emission specifications and relevant propagation modelling as part the acoustic assessment. However, in light of the available information and scientific reviews detailed here, it is considered that specific and targeted assessment of LFN content of noise emissions from the proposals is not necessary.

3 Infrasound

In relation to infrasound in general, frequencies below 20 Hz may be audible, although tonality is lost below 16 - 18 Hz, thus losing a key element of perception [1]. In relation to modern, upwind turbines; there is strong evidence that the levels of infrasound produced are well below the average threshold of human hearing [2]. The DTI report [5] discussed earlier extended this conclusion to more sensitive members of the population, stating that *"Even assuming the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion"*. As such, *"infrasound from wind turbines is not audible at close range and even less so at distances where residents are living"* [3].

In February 2005, the BWEA (now known as RenewableUK) published background information on low frequency noise from wind farms [8]. In conclusion, the report states that *"It has been repeatedly shown, by measurements of wind turbine noise undertaken in the UK, Denmark, Germany and the USA over the past decade, and accepted by experienced noise professionals, that the levels of infrasonic noise and vibration radiated from modern upwind configuration wind turbines are at a very low level; so low that they lie below the threshold of perception, even for those people who are particularly sensitive to such noise, and even on an actual wind turbine site"*. The report goes on to quote Dr Geoff Leventhall, author of the DEFRA report on *"Low Frequency Noise and its Effects' [1], as saying: "I can state, quite categorically, that there is no significant infrasound from current designs of wind turbines"*.

With regard to health effects, the DTI report [5] quotes the document 'Guidelines for Community Noise', prepared for the World Health Organisation (WHO) [25], which states that *'there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects'*. The DTI report goes on to conclude that '*infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour*'.

Furthermore, researchers at Keele University [9] explain that '*The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect the low frequency sound. There is no scientific evidence to suggest that infrasound has an impact on human health*'.

In January 2013 the Environment Protection Authority, South Australia, presented their findings of a study [10] into the level of infrasound within typical environments with a particular focus on comparing wind farm environments to urban and rural environments away from wind farms. The report states that *'This study concludes that the level of infrasound at houses near the wind turbines assessed is no greater than that experienced in other urban and rural environments, and is also significantly below the human perception threshold. Also, that the contribution of wind turbines to the measured infrasound levels is insignificant in comparison with the background level of infrasound in the environment'*.

The Australian Medical Association issued a position statement which detailed their findings on the health impacts due to the generation of infrasound from wind turbines in March 2014 [11]. The findings concluded that *'The available Australian and international evidence does not support the view that the infrasound or low frequency sound generated by wind farms, as they are currently regulated in Australia, causes adverse health effects on populations residing in their vicinity. The infrasound and low frequency sound generated by modern wind farms in Australia is well below the level where known health effects occur, and there is no accepted physiological mechanism where sub audible infrasound could cause health effects'*.

In April 2015, at the International Conference on Wind Turbine Noise in Glasgow, various papers were presented on LFN and infrasound. The findings of the research work undertaken were as follows.

A paper by Berger et al [12], investigated whether current audible noise-based guidelines for wind turbines account for the protection of human health, given the levels of infrasound and low frequency noise typically produced by wind turbines. New field measurements of indoor infrasound and outdoor low frequency noise at locations between 400 m and 900 m from the nearest turbine, which were previously underrepresented in the scientific literature, are reported and put into context with existing published work. The findings concluded that *'The analysis showed that indoor IS [infrasound] levels were below auditory threshold levels while LFN [low frequency noise] levels at distances >500 m were similar to background LFN levels. Overall, the available data from this and other studies suggest that health-based audible noise wind turbine siting guidelines provide an effective means to evaluate, monitor, and protect potential receptors from audible noise as well as IS and LFN'*.

Research by Hansen et al [13] proposed to examine the effect of infrasound tonal components on perceived low frequency noise annoyance for short exposure durations. The investigated spectra were synthesized based on measured wind turbine noise, which consisted of amplitude modulated tonal components. Listening tests were developed, based on data measured outside a residence, 1.3 km from a wind farm in South Australia. The research concluded that *'For evaluation times of 5 minutes, it has been shown that for the persons tested, the presence of infrasound at realistic levels does not influence audibility, annoyance or ability to fall asleep'*.

Leventhall [14] presented a paper which assesses the scientific basis of the "Plympton-Wyoming bylaw". This is a bylaw which has recently introduced limits on infrasound from wind turbines. The author concludes that *'Science does not support the conditions of the bylaw, which is largely aimed at restricting blade pass tones. There is no evidence that the very low level of blade pass tones affects humans, whilst there is evidence that it does not'*.

The work carried out by Tonin et al [15] was an investigation into the effect on the reported pathological symptoms of simulated infrasound produced by wind turbines. The infrasound waveform was generated using a custom-made headphone apparatus. Volunteers were manipulated into states of either high or low expectancy of negative effects from infrasound and their reactions to either infrasound or a sham noise were recorded in a double-blind experiment. The findings of the investigation state that *'It was found, at least for the short-term exposure times conducted here-in,* *that the simulated infrasound has no statistically significant effect on the symptoms reported by volunteers, however the state of prior concern that volunteers had about the effect of infrasound has a statistically significant influence'*.

A study by Walker & Celano [16] considered the subjective effects of wind turbine noise in a controlled environment and how to faithfully generate acoustic signatures produced by actual turbines. Field measurements indicate that theses signatures encompass a wide frequency range, extending from below 1 Hz to several kHz. The authors present conceptual descriptions and preliminary demonstrations of an infrasound synthesizer that is capable of producing turbine-faithful signals at least 10 dB greater than experienced in the field. The authors concluded from their research *'It has been demonstrated that simulation of wind turbine noise and infrasound levels representative of those observed at distances of 100 meters can be accomplished in a typical residential-sized room with a modest array of electro-acoustic actuators. To date, subjective reactions to the synthesized signals are not conclusive due to the small number of test subjects and constrained exposure times. However, no individual thus far has reported any sensation when exposed to infrasound alone at peak levels up to 97 dB'*.

A study [17] undertaken by Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg (LUBW) for the Ministry for the Environment, Climate and Energy of the Federal State of Baden-Wuerttemberg, published in 2016, shows the variety in levels of infrasound typically experienced by humans on a daily basis, including that generated by wind turbines, traffic, natural sources and from appliances found in homes. The report states that *'Infrasound is caused by a large number of different natural and technical sources. It is an everyday part of our environment that can be found everywhere. Wind turbines make no considerable contribution to it. The infrasound levels generated by them lie clearly below the limits of human perception. There is no scientifically proven evidence of adverse effects in this level range'*.

Another study into infrasound, commissioned by the Finnish government [18] found that the presence of wind turbines resulted in infrasonic levels that were similar to that found within more urban environments, although with levels being still well below recognised perception thresholds. A laboratory study was also undertaken whereby several individuals who self-reported health effects resulting from living near to turbines and a group of people who did not were exposed to varying levels of noise and infrasound. In conclusion, the report states that '*The detection experiment showed no evidence for sensitivity for infrasound in wind turbine noise, or increased sensitivity for infrasound in the WTRS [Wind Turbine Related Symptoms] group*' and that '*The annoyance experiment indicated that infrasound is not causing increased annoyance associated with wind turbine sound. Instead, potential annoyance is more related to intensity and amplitude modulation of turbine sound*'.

An Australian study [19] entitled 'The Health Effects of 72 Hours of Simulated Wind Turbine Infrasound: A Double-Blind Randomized Crossover Study in Noise-Sensitive, Healthy Adults' aimed to '*…test the effects of 72 h of infrasound (1.6–20 Hz at a sound level of ~90 dB pk re 20 l Pa, simulating a wind turbine infra-sound signature) exposure on human physiology, particularly sleep*'. The study did *not '… support the idea that infrasound causes WTS [Wind Turbine Syndrome]. High level, but inaudible, infrasound did not appear to perturb any physiological or psychological measure tested in these study participants*'. However, the conclusion is subject to the findings being independently verified.

The Centre for Sustainable Energy published 'Common concerns about wind power' in June 2017 [20]. The document contains a chapter entitled 'Infrasound, 'wind turbine syndrome' and other health concerns' which provides a detailed review of publications relating to these topics by various authors. The summary to the chapter states that the '*… theory that infrasound from wind turbines might be causing real, physiological effects on nearby residents has so far failed to produce any empirical evidence or, indeed, even a plausible mechanism. The persistence of 'wind turbine syndrome' as a reason for rejecting wind farm developments seems to be more closely linked to the expectation of negative health effects from proposed and existing wind power facilities, an expectation that has been driven by largely unfounded reports from media and campaign groups about potential health impacts. This has entrenched the idea of wind turbines as one more modern malaise that contributes to a variety of non-specific health problems. This has parallels with other modern health worries, such as concerns over the presence of electromagnetic fields, where there is a common pattern of* *sufferers' symptoms and associated psychological distress being attributable to the 'nocebo' effect rather than any physical stimulus'.*

Therefore, in accordance with literature, it is not considered appropriate or relevant to undertake specific assessment in relation to infrasound for the Proposed Development.

4 Sleep Disturbance

Research evidence supports the conclusion that noise from any kind of noise source would result in measurable effects on sleep when it reaches a certain level. Such effects may comprise changes in sleep state, without those exposed actually awakening, or they may comprise complete awakenings. These responses may or may not have a consequential long-term effect on wellbeing depending on the subjects concerned and the extent of the effects being considered.

There is no reason why wind turbine noise should be any different to other forms of noise, in that there will be a certain level at which wind turbine noise would impact on the sleep of those exposed to it. As with other forms of noise, some variability in response across the exposed population would be expected, with some people being more noise sensitive and others more noise tolerant or habituated to the environment they live in.

While some studies have found an association between wind turbine noise and sleep disturbance, others have not [21]. A selection of these studies is summarised below, followed by an explanation of how the night-time noise limit recommended by the

ETSU-R-97 [22] guidelines, used to assess wind farm noise in the UK, was derived and an outline of the latest WHO advice.

A review undertaken by the Chief Medical Officer of Health of Ontario [23] in response to public health concerns about wind turbine noise concluded that '...*while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects...*'.

A report [24] published the Massachusetts Department of Environmental Protection concludes that ‘*Evidence regarding wind turbine noise and human health is limited. There is limited evidence of an association between wind turbine noise and both annoyance and sleep disruption, depending on the sound pressure level at the location of concern*’.

A study carried out by Health Canada [25] found that self-reported sleep (including general disturbance, use of sleep medication, diagnosed sleep disorders and sleep quality) was not associated with wind turbine noise exposure. Furthermore, when sleep quality was measured objectively, calculated wind turbine noise levels outside the participants’ homes were not found to be associated with sleep efficiency, the rate of awakenings, duration of awakenings, total sleep time, or how long it took to fall asleep.

In contrast to the conclusions of the three studies described above, a report entitled ‘Sleep Disturbance and Wind Turbine Noise’ [26] by Dr Christopher Hanning reviewed the potential consequences of wind turbine noise and its effect on sleep and health, making recommendations on setback distances. The report was created on behalf of ‘Stop Swinford Wind Farm Action Group’ (SSWFAG) and states that *‘There can be no doubt, that groups of industrial wind turbines (“wind farms”) generate sufficient noise to disturb the sleep and impair the health of those living nearby*’.

In another article by Dr Hanning and Professor Alun Evans published in the British Medical Journal [27] states *‘A large body of evidence now exists to suggest that wind turbines disturb sleep and impair health at distances and external noise levels that are permitted in most jurisdictions, including the United Kingdom*’.

A criticism of Dr Hanning’s work is its focus on recommending a fixed setback distance between wind turbines and residential properties. This generalisation obscures the link between noise level and sleep disturbance in that it does not account for variations in the size of wind farm sites and differences in the noise levels emitted by different turbine types. Care is required when interpreting the findings of studies undertaken in multiple countries as different noise limits would likely apply such that the participants could be exposed to different noise levels. It might also be the case that the relevant noise guidance for a given country has changed over time such that older wind farms were assessed against different standards. Other differences between countries might include the specification of a noise limit that applies for all times of the day or separate limits for day and night-time periods respectively. If separate limits for day and night-time periods are defined it may be the case that the noise limit for one period effectively restricts the amount of noise that can be emitted during the other period such that the limit for the period where a higher limit is permitted on paper is rarely, if ever, reached in practice.

The wind farm noise guidance applicable to the United Kingdom (UK), ETSU R 97, states that different limits should be applied during daytime and night-time periods. The daytime limits are intended to preserve outdoor amenity, while the night-time limits are intended to prevent sleep disturbance. A lower fixed limit of 35-40 dB L_{A90} applies during daytime periods. The night-time lower fixed limit of 43 dB L_{A90} is derived from the 35 dB(A) sleep disturbance criterion referred to in ETSU R 97, with an allowance of 10 dB for attenuation through an open window (which is at the conservative end of the 10 – 15 dB range deemed typical) and a correction of 2 dB to allow for the use of L_{A90}, rather than L_{Aeq}.

The 35 dB(A) sleep disturbance criterion was consistent with WHO advice at the time [28]. The WHO Guidelines for Community Noise [29], published in 1995, reduced the indoor limit to 30 dB L_{Aeq} but translated this into an outdoor limit of 45 dB L_{Aeq} which remained consistent with the recommendations of ETSU-R-97.

The Night Noise Guidelines for Europe [30], published by the WHO in 2009, recommend target levels for the protection of public health from night-time noise. The limits proposed were aspirational and were not formally adopted by any EU Member State. The Night Noise Guideline (NNG) is an outdoor annualised free field noise level of 40 dB L_{Aeq} during night-time periods. An interim target of 55 dB L_{Aeq} is recommended in situations where the NNG is not feasible in the short term. Annual averaging would allow noise levels in excess of 40 dB L_{Aeq} to occur for a certain amount of the time without the NNG being breached. The WHO guidelines are therefore not directly comparable to the noise limits for the Proposed Development derived from ETSU-R-97 as these are specified as levels that should not be exceeded. Likewise, the predicted wind farm noise levels shown in the acoustic assessment are not directly comparable to the NNG as they do not represent annual average night-time values. The annual average wind farm noise level would depend upon the range of wind speeds and wind directions experienced during night-time periods over the year in question.

The Environmental Noise Guidelines for the European Region [31], published by the WHO in 2018, are described as complementary to the Night Noise Guidelines, stating that '*No statistically significant evidence was available for sleep disturbance related to exposure from wind turbine noise at night*'.

Since ETSU-R-97 accounts for sleep disturbance in the setting of the night-time noise limits and continues to be endorsed by planning guidance, it is concluded that protection from sleep disturbance is considered within the acoustic impact assessment for the Proposed Development.

5 Vibration

Structure borne noise, originating in vibration, is also low frequency, as is neighbour noise heard through a wall, since walls generally block higher frequencies more than lower frequencies.

In 2004/2005 researchers at Keele University investigated the effects of the extremely low levels of vibration resulting from wind farms on the operation of the seismic array at Eskdalemuir [32], one of the most sensitive installations in the world. The results of this study have frequently been misinterpreted and, to clarify the position [9], the authors have explained that '*The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect*'. They go on to say that '*Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise - they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health*'.

The Ministry of Defences' (MOD) approach to safeguarding the Eskdalemuir seismic array (EKA) is to allocate a budget in terms of the cumulative level of seismic vibration from wind turbines. This restricts the number of wind farms that can be located within a certain distance of the EKA without adversely impacting upon its operation. In June 2014, a report was prepared by Xi Engineering Consultants [33] with the full cooperation and significant input from the MOD. The report builds on initial Phase 0 work which identified that the current budget overestimates the seismic vibration produced by wind turbines and that there is a likelihood of significant prospective head room that would allow the building of wind farms without breaching the 0.336 nm threshold. The goal of the research was to produce an algorithm that could better predict the amplitude of seismic vibrations produced by wind turbines in the 0.5 to 0.8 Hz passband, which might allow the exploitation of wind resource in the Southern Uplands while maintaining protection of the detection capabilities of EKA. The work of the research allows for the determination of how close to EKA wind turbines can be built while optimising the generating capacity within the consultation zone. The application of a physics-based algorithm allowed for the calculation of cumulative seismic vibration at EKA. From these calculations they were able to predict that *'The cumulative amplitude of all turbines currently allocated budget and currently subject to objection with a utilisation factor of unity and minimum hub height of 40 m is 0.193833 nm'*. This value falls well below the 0.336 nm threshold as set by the MOD.

A scientific advisory panel comprising independent experts in acoustics, audiology, medicine and public health conducted a comprehensive review of the available literature on the issue of perceived health effects of wind turbines, titled 'Wind Turbine Sound and Health Effects - An Expert Panel Review', and prepared a report for the American and Canadian Wind Energy Associations in December 2009 [34]. The authors explain that *'Vibration of the body by sound at one of its resonant frequencies occurs only at very high sound levels and is not a factor in the perception of wind turbine noise' and that 'Airborne sound can cause detectable body vibration, but this occurs only at very high levels - usually above sound pressure levels of 100 dB. There is no scientific evidence to suggest that modern wind turbines cause perceptible vibration in homes or that there is an associated health risk'*.

The LUBW report [17] discussed earlier also provides further information relating to vibration from the operation of wind turbines. In relation to a particular model of turbine the report states that the *'… ground vibrations* *emanating from wind turbines can be detected by measurement. Already at a distance of less than 300 m from the turbine, they have dropped so far that they can no longer be differentiated from the permanently present background noise [background vibration]. No relevant vibrational effects can be expected at residential buildings'*.

Therefore, in accordance with relevant literature and evidence reviews, it is not considered appropriate or relevant to undertake specific assessment in relation to vibration caused by the operation of the Proposed Development.

6 Aerodynamic/Amplitude Modulation

A noise sometimes associated with wind turbines and commonly referred to as 'blade swish' is the modulation of aerodynamic noise produced at blade passing frequency (the frequency at which a blade passes a fixed point). This noise character is acknowledged by, and accounted for, in the recommendations of ETSU-R-97 [18]. However, the DTI report [5] mentioned earlier noted that 'Aerodynamic Modulation', alternatively referred to as 'Amplitude Modulation' (AM) was, in some isolated circumstances, occurring in ways not anticipated by ETSU-R-97. AM above and beyond that considered by ETSU-R-97 is often referred to as Excess, or Other, Amplitude Modulation (EAM/OAM).

In December 2013, the wind industry trade association, RenewableUK (RUK), published detailed new scientific research [35] into causes and effects of wind turbine AM. The work was carried out by a group of independent experts, including academics from the Universities of Salford and Southampton, the National Aerospace Laboratory of the Netherlands, Hoare Lea Acoustics, Robert Davies Associates and DTU Risø in Denmark. The Chairman of the IOA Noise Working Group said of the study that *'This research is a significant step forward in understanding what causes amplitude modulation from a wind turbine, and how people react to it'*.

The RUK work encouraged further research in the area, which has led to the identification of suitable mitigation methods. At the EWEA Technology Workshop on Wind Turbine Sound in 2014, Hoare Lea Acoustics presented a paper entitled 'Measurements to assess the effectiveness of turbine modifications to reduce the occurrence of AM in the far-field' [36]. The paper concludes that turbine blade modifications can result in significant reductions in AM in the far-field and that similar effects can also be achieved through blade pitch modification. The authors state that '*This shows that effective mitigation of AM on operational turbines is technically feasible*'.

The other notable outcome of the RUK research was a proposed planning condition informed by listening tests and work undertaken to determine how AM should be measured. The IOA recommended a period of testing and validation before the condition was adopted such that the work again proved valuable as a catalyst for further research.

The IOA created a dedicated AM Working Group to undertake the further testing and validation recommended. A discussion document [37] on methods for rating amplitude modulation in wind turbine noise was published in April 2015. The document proposed a definition of AM and provided a literature review of the available metrics before selecting three for detailed discussion. The intention was to obtain feedback from the acoustic community, allowing a preferred rating method to be selected following the consultation period. The final report [38], detailing the recommended metric for the quantification of the level of AM in wind turbine noise, and the reasoning behind it, was published in August 2016.

A separate, government funded, study was commissioned by the Department of Energy and Climate Change (DECC) with a view to recommending how an appropriate AM threshold should be defined. A report summarising the work [39], undertaken by WSP Parsons Brinkerhoff, was published in August 2016 and proposes an appropriate penalty scheme informed by studies into subjective response to a given level of AM.

There is therefore a method of quantification of the level of AM over a given 10-minute period and the appropriate penalty to apply where necessary. This is in addition to any penalty relating to tonal noise.

Currently, there is no standard or agreed method by which to predict with any certainty, the likelihood of AM occurring at a level requiring a penalty, only some possible indicators such as relatively high wind shear conditions under certain circumstances or specific turbine designs and/or dimensions for example.

Appropriate elements for a planning condition to control AM were proposed by the acoustic experts undertaking the research. The specific wording for a condition was not within the scope of the research report and it was noted that legal advice would be required to ensure any proposed condition for a particular proposal met the necessary policy guidance tests.

7 Wind Turbine Syndrome

The condition proposed by paediatrician Dr Nina Pierpont in her report 'Wind Turbine Syndrome: A Report on a Natural Experiment' [40] cites a range of physical sensations and effects as being caused by living near a wind farm. This study is based on a series of interviews comprising a study group of 10 families and is a self-published report, with none of the research being published in any peer reviewed medical journal.

A response to the Pierpont report provided by the NHS, a report titled 'Are wind farms a health risk?', states that there is no conclusive evidence that wind turbines influence health or are causing the set of symptoms described as 'wind turbine syndrome' [41]. It was noted that the group study by Pierpont was not sufficient to grant the claims stated.

The aforementioned 'Wind Turbine Sound and Health Effects - An Expert Panel Review' [34], prepared by a scientific advisory panel for the American and Canadian Wind Energy Associations, concludes that Wind Turbine Syndrome is *'not a recognized medical diagnosis, is essentially reflective of symptoms associated with noise annoyance and is an unnecessary and confusing addition to the vocabulary on noise'*. The report goes on to say that '*There are no unique symptoms or combinations of symptoms that would lead to a specific pattern of this hypothesized disorder'*.

An independent review of the state of knowledge about the alleged health condition was carried out. The report [42] includes three expert opinions provided by: Richard J.Q. McNally - Reader in Epidemiology at the Institute of Health and Society Newcastle University; Geoff Leventhall – an independent consultant specialising in low frequency noise, infrasound and vibration; and Mark E. Lutman - Professor of Audiology at the University of Southampton. Their critique of Pierpont's study concludes that the reported symptoms are the effects mediated by stress and anxiety when exposed to an adverse element in their environment. There is no evidence that they are pathophysiological effects of wind turbine noise.

A paper [43] by Pedersen explores data from three cross-sectional studies comprising A-weighted sound pressure levels of wind turbine noise, and subjectively measured responses from 1,755 people, to find the relationships between sound levels and aspects of health and well-being. It was concluded that there is no consistent association between wind turbine noise exposure and the symptoms associated with Wind Turbine Syndrome (WTS).

A study [44] conducted by Simon Chapman, Professor of Public Health at Sydney University, provides evidence that noise and health complaints about wind turbines are psychogenic. The authors conclude that *'In view of scientific consensus that the evidence for wind turbine noise and infrasound causing health problems is poor, the reported spatiotemporal variations in complaints are consistent with psychogenic hypotheses that health problems arising are communicated diseases with nocebo effects likely to play an important role in the aetiology of complaints'*.

Therefore, in accordance with the literature and studies detailed above and the review provided by the Centre for Sustainable Energy [20], it is not considered appropriate or relevant to undertake an assessment with respect to 'wind turbine syndrome'.

8 Health Effects

In 2014 Health Canada released the findings of 'Wind Turbine Noise and Health Study' [25]. Health Canada, in partnership with Statistics Canada, conducted the study between residents of southern Ontario and Prince Edward Island where there were sufficient homes within the vicinity of wind turbine installations. Twelve and six wind turbine developments were sampled in Ontario and PEI, representing 315 and 84 wind turbines respectively. All potential homes within approximately 600 m of a wind turbine were selected, as well as a random selection of homes between 600 m and 10 km. A total of 1,238 households participated out of a possible 1,570.

The study was comprised of three parts: an in-person questionnaire given to randomly selected participants living at various distances from wind turbines; a collection of physical health measures that assessed stress levels using hair cortisol, blood pressure and resting heart rate as well as measures of sleep quality; and more than 4,000 hours of wind turbine noise measurements conducted by Health Canada to support calculations of wind turbine noise levels (WTN) in all homes in the study. The findings were separated into five parts: illness and chronic disease; stress; sleep; annoyance; and quality of life and noise.

Under Self-Reported Illnesses and Chronic Diseases, Health Canada states that '*Self-reports of having been diagnosed with a number of health conditions were not found to be associated with exposure to WTN levels. These conditions included, but were not limited to chronic pain, high blood pressure, diabetes, heart disease, dizziness, migraines, ringing, buzzing or whistling sounds in the ear (i.e., tinnitus)*'.

Under the heading of Self-Reported Stress, Health Canada states no association was found between the multiple measures of stress (such as hair cortisol, blood pressure, heart rate, self-reported stress) and exposure to wind turbine noise. The study states that '*Self-reported stress, as measured by scores on the Perceived Stress Scale, was not found to be related to exposure to WTN levels*'.

For Self-Reported Sleep the study suggests that *'Results of self-reported measures of sleep, that relate to aspects including, but not limited to general disturbance, use of sleep medication, diagnosed sleep disorders and scores on the Pittsburgh Sleep Quality Index (PSQI), did not support an association between sleep quality and WTN levels*'. However, the study states, while some people reported some of the health conditions listed above, their existence was not found to change in relation to exposure to wind turbine noise.

An association was found between increasing levels of wind turbine noise and individuals reporting to be very or extremely annoyed. No association was found with any significant changes in reported quality of life or with overall quality of life and satisfaction with health. This was assessed using the abbreviated version of the WHO's Quality of Life Scale. The report states that '*The overall conclusion to emerge from the study findings is that the study found no evidence of an association between exposure to WTN and the prevalence of self-reported or measured health effects beyond annoyance. Collectively, the findings related to annoyance suggest that health and well-being effects may be partially related to activities that influence community annoyance, over and above exposure to WTN. Therefore, efforts that aim to identify and mitigate high levels of* *annoyance with wind turbines may have benefits that go beyond annoyance'*. Furthermore, calculated noise levels were found to be below levels that would be expected to directly affect health, according to the WHO Community Noise Guidelines, 1999.

A review conducted by McCunney et al in November 2014 [45], examines the literature related to health effects of wind turbines. The review was intended to assess the peer-reviewed literature regarding evaluations of potential health effects among people living in the vicinity of wind turbines. It included analysis and commentary of the scientific evidence regarding potential links to health effects, such as stress, annoyance, and sleep disturbance, among others, that have been raised in association with living in proximity to wind turbines. Specific components of noise associated with wind turbines such as infrasound and low-frequency sound and their potential health effects were also addressed. The review attempts to address the following questions regarding wind turbines and health: *'Is there sufficient scientific evidence to conclude that wind turbines adversely affect human health? If so, what are the circumstances associated with such effects and how might they be prevented?'; 'Is there sufficient scientific evidence to conclude that psychological stress, annoyance, and sleep disturbance can occur as a result of living in proximity to wind turbines? Do these effects lead to adverse health effects? If so, what are the circumstances associated with such effects and how might they be prevented?'*; and, '*Is there evidence to suggest that specific aspects of wind turbine sound such as infrasound and low-frequency sound have unique potential health effects not associated with other sources of environmental noise?'*.

The co-authors represent professional experience and training in occupational and environmental medicine, acoustics, epidemiology, otolaryngology, psychology, and public health.

The findings of the review are that *'measurements of low-frequency sound, infrasound, tonal sound emission, and amplitude-modulated sound show that infrasound is emitted by wind turbines. The levels of infrasound at customary distances to homes are typically well below audibility thresholds'; 'No cohort or case-control studies were located in this updated review of the peer-reviewed literature. Nevertheless, among the cross-sectional studies of better quality, no clear or consistent* *association is seen between wind turbine noise and any reported disease or other indicator of harm to human health'*; *'Components of wind turbine sound, including infrasound and low-frequency sound have not been shown to present unique health risks to people living near wind turbines'*; and, that '*Annoyance associated with living near wind turbines is a complex phenomenon related to personal factors. Noise from turbines plays a minor role in comparison with other factors in leading people to report annoyance in the context of wind turbines'*.

The WHO's Environmental Noise Guidelines [31] conditionally recommend that average exposure to wind turbine noise is limited to 45 dB L_{den} as wind turbine noise above this level is associated with adverse health effects. The recommendation is conditional as evidence of the adverse effects of wind turbine noise was rated as being of low quality. The limit is set at this level as there was deemed to be sufficient, albeit still low quality, evidence that this represented the threshold at which 10 % of people would be expected to be highly annoyed. The risk of other health outcomes at given levels of wind turbine noise could not be assessed due to a lack of evidence.

The day-evening-night level (L_{den}) is an annual average L_{Aeq} with a 5 dB penalty applied to noise levels occurring during the evening and a 10 dB penalty applied to noise levels during the night. The WHO limit is not directly comparable to the noise limits for the Proposed Development derived from ETSU R-97 which are specified as L_{A90} levels that should not be exceeded. Likewise, the predicted wind farm noise levels shown in the acoustic assessment are not directly comparable to the WHO limit as they do not represent annual average values and do not have the penalties applicable during evening and night-time periods applied. The annual average wind farm noise level experienced by nearby residents would depend upon the range of wind speeds and wind directions over the year in question.

Given the lack of evidence of health effects caused by wind turbine noise, the conditional nature of the WHO guidance and the continued endorsement of ETSU-R-97 by planning policy, no additional assessment of health effects due to the Proposed Development has been undertaken.

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