Technical Appendix 10.2: Scope of Assessment

Low Frequency Noise

10.2.1 The frequency range of 'audible noise' is generally taken to be 20 Hz to 20,000 Hz, 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', 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 the literature.

10.2.2 Low frequency noise is always present, even in an ambient 'quiet' background[1]. It is generated by natural sources, including the sea, earthquakes, the rumble of thunder and wind. It is additionally an emission from many artificial sources found in modern life, such as household appliances (e.g. washing machines, dishwashers) and all forms of transport.

10.2.3 Noise emitted from wind turbines covers a broad spectrum from low to high frequencies. In relation to human perception of the broadband noise produced by wind turbines, the dominant frequency range is not the low frequency or infrasonic ranges[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 'low frequency noise' would be below the average hearing threshold.

10.2.4 A comprehensive literature review of 'Low Frequency Noise and Infrasound Associated with Wind Turbine Generator Systems', 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[2]. The degree of audibility depends upon the wind conditions, the degree of masking from background noise sources and the distance from the wind turbines[2].

10.2.5 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[3].

10.2.6 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 the Hayes McKenzie Partnership

[1] 'A Review of Published Research on Low Frequency Noise and Its Effects', Leventhall, Report for DEFRA, 2003

[2] 'Low Frequency Noise and Infrasound Associated with Wind Turbine Generator Systems, a Literature Review', Ontario Ministry of the Environment, OSS078696, December 2010

[3] 'Infrasound and low frequency noise from wind turbines: exposure and health effects', Bolin et al, Environmental Research Letters Volume 6, September 2011

[4] 'A literature review of infra and low frequency noise from wind turbines: exposure and health effects', prepared for Swedish Environmental Protection Agency, November 2011

to perform an independent study to investigate these claims[5]. The Government released the following advice based on the report's findings[6]:

"The report concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines."

10.2.7 This is re-iterated in the review undertaken for the Ontario Ministry for the Environment, which concludes that publications by medical professionals indicate 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.

10.2.8 The Oregon Health Authority's Public Health Division conducted a strategic Health Impact Assessment in response to a convergence of questions about potential health impacts from wind energy facilities in Oregon. The report, titled 'Strategic Health Impact Assessment on Wind Energy Development in Oregon[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".

10.2.9 Whilst low frequency content of the noise from wind farms shall be considered through the use of octave band specific noise emission and propagation modelling within the assessment presented here, it is considered that specific and targeted assessment on low frequency content of noise emissions from the proposed wind farm is not necessary in light of available information and scientific reviews detailed above.

Infrasound

10.2.10 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 aforementioned DTI report extended this conclusion to more sensitive members of the population[5]:

"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".

10.2.11 As such[3]:

"infrasound from wind turbines is not audible at close range and even less so at distances where residents are living".

[5] 'The Measurement of Low Frequency Noise at Three UK Wind Farms', Hayes, Contract Number W/45/00656/00/00, URN 06/1412, 2006, www.berr.gov.uk/files/file31270.pdf

[6] 'Advice on findings of the Hayes McKenzie report on noise arising from Wind Farms', DTI, URN 06/2162, November 2006, www.berr.gov.uk/files/file35592.pdf

[7] 'Strategic Health Impact Assessment on Wind Energy Development in Oregon', Sujata Joshi et al, Prepared By: Public Health Division Oregon Health Authority, March 2013, www.healthimpactproject.org

10.2.12 In February 2005, the BWEA[8] published background information on low frequency noise from wind farms[9]. The conclusion 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".

10.2.13 The BWEA report goes on to quote Dr Geoff Leventhall, author of the DEFRA report on 'Low Frequency Noise and its Effects', as saying:

"I can state, quite categorically, that there is no significant infrasound from current designs of wind turbines".

10.2.14 With regard to health effects, the DTI report quotes the document 'Community Noise', prepared for the World Health Organisation (WHO), which states that[5]:

"there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects".

10.2.15 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".

10.2.16 Furthermore, researchers at Keele University 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."[10]

10.2.17 In January 2013 the Environment Protection Authority, South Australia, presented their findings of a study 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[11]. The report states:

"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."

10.2.18 The Australian Medical Association[12] in March 2014 issued a position statement which detailed their findings on the health impacts due to the generation of infrasound from wind turbines. The findings concluded that:

[8] BWEA is now known as RenewableUK, a group representing the concerns of companies in the Renewable Energy Industry

[9] 'Low Frequency Noise and Wind Turbines', The British Wind Energy Association, 2005, www.bwea.com/ref/lowfrequencynoise.html & Technical Annex www.bwea.com/pdf/lfn-annex.pdf

[10] 'Wind farm noise', Styles, & Toon, printed in the Scotsman newspaper as a rebuttal of claims made by the Renewable Energy Foundation, August 2005

[11] 'Infrasound Levels Near Windfarms and in Other Environments' Environment Protection Authority & Resonate Acoustics, January 2013, www.epa.sa.gov.au

[12] "AMA Position – Wind Farms and Health 2014", Australian Medical Association, March 2014

"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".

10.2.19 In April 2015, at the International Conference on Wind Turbine Noise in Glasgow[13], a number of papers were presented on Low Frequency Noise and Infrasound. The findings of the research work undertaken were as follows.

10.2.20 A paper by Berger et al[14], investigates 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 400m and 900m 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 >500m 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".

10.2.21 Research by Hansen et al[15] 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."

10.2.22 Leventhall[16] 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:

[13] International Conference on Wind Turbine Noise, An INCE Series of International Conferences on Wind Turbine Noise Held Biennially, Wind Turbine Noise 2015, 20th – 23rd April 2015, Glasgow

[14] "Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines", Berger et al, Sixth International Meeting on Wind Turbine Noise, Glasgow 20-23 April 2015, Frontiers in Public Health, 24 February 2015

[15] "Perception and annoyance of low frequency noise versus infrasound in the context of wind turbine noise", Hansen et al, Sixth International Meeting on Wind Turbine Noise, Glasgow 20-23 April 2015

[16] "On the overlap region between wind turbine infrasound and infrasound from other sources and its relation to criteria", G Leventhall, Sixth International Meeting on Wind Turbine Noise, Glasgow 20-23 April 2015

"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."

10.2.23 The work carried out by Tonin et al[17] 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."

10.2.24 A study by Walker & Celano[18] 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 1Hz 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."

10.2.25 Therefore, in accordance with literature, it is not considered appropriate or relevant to undertake specific assessment in relation to infrasound for the proposed wind farm.

Sleep Disturbance

10.2.26 Research evidence supports the conclusion that noise from any 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. Either of 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.

10.2.27 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

[17] "Response to Stimulated Wind Farm Infrasound Including Effect of Expectation", Tonin et al, Sixth International Meeting on Wind Turbine Noise, Glasgow 20-23 April 2015

[18] "Progress Report on Synthesis of Wind Turbine Noise and Infrasound", Walker & Celano, Sixth International Meeting on Wind Turbine Noise, Glasgow 20-23 April 2015

response across the exposed population would be expected, with some people being more noise sensitive and others more noise tolerant.

10.2.28 While some studies have found an association between wind turbine noise and sleep disturbance, others have not[19]. 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[20] guidelines, used to assess wind farm noise in the UK, was derived and an outline of the latest WHO advice.

10.2.29 A review undertaken by the Chief Medical Officer of Health of Ontario[21] 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..."

10.2.30 A report published the Massachusetts Department of Environmental Protection concludes that[22]:

"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".

10.2.31 A study carried out by Health Canada[23] 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.

10.2.32 In contrast to the conclusions of the three studies described above, a report entitled 'Sleep Disturbance and Wind Turbine Noise' by Dr Christopher Hanning reviewed the potential consequences of wind turbine noise and its effect on sleep and health, making recommendations on setback distances[24]. 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."

10.2.33 In another article by Dr Hanning and Professor Alun Evans published in the British Medical Journal[25] it states:

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[19] 'A Review of the Potential Impacts of Wind Farm Noise on Sleep', Micic et al., Acoustics Australia, February 2018

[20] 'The Assessment and Rating of Noise from Wind Farms', The Working Group on Noise from Wind Turbines, ETSU Report for the DTI, ETSU-R-97

[21] 'The Potential Health Impact of Wind Turbines', Chief Medical Officer of Health (CMOH) Report, May 2010

[22] 'Wind Turbine Health Impact Study: Report of Independent Expert Panel'" Jeffrey M. Ellenbogen et al, Prepared for: Massachusetts Department of Environmental Protection Massachusetts Department of Public Health, January 2012

[23] "Wind Turbine Noise and Health Study: Summary of Results", Health Canada, November 2014, http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php

[24] 'Sleep Disturbance and Wind Turbine Noise', Hanning, on behalf of Stop Swinford Wind Farm Action Group (SSWFAG), June 2009

[25] 'Wind Turbine Noise', Hanning et al, British Medical Journal, March 2012

"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."

10.2.34 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 in 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 at all times or separate limits for day and night time periods. 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.

10.2.35 UK wind farm noise guidance, 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}.

10.2.36 The 35 dB(A) sleep disturbance criterion was consistent with WHO advice at the time[26]. The WHO Guidelines for Community Noise[27], 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.

10.2.37 The Night Noise Guidelines for Europe[28], published by the WHO in 2009, recommend target levels for the protection of public health from night time noise. The limits proposed are aspirations and have yet to be 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

[26] WHO Environmental Health Criteria 12 - Noise: 1980

[27] WHO Guidelines for Community Noise, 1995

[28] 'Night Noise Guidelines for Europe', World Health Organisation, 2009

depend upon the range of wind speeds and wind directions experienced during night time periods over the year in question.

10.2.38 The Environmental Noise Guidelines for the European Region[29], published by the WHO in 2018, are described as complementary to the Night Noise Guidelines and state that:

"No statistically significant evidence was available for sleep disturbance related to exposure from wind turbine noise at night."

10.2.39 Since ETSU-R-97 accounted for sleep disturbance when setting 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 of the Proposed Development.

Vibration

10.2.40 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.

10.2.41 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, one of the most sensitive installations in the world[10]. The results of this study have frequently been misinterpreted and, to clarify the position, 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."

10.2.42 They go on to say:

"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."

10.2.43 The Ministry of Defence's approach to safeguarding the Eskdalemuir seismic array 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 Eskdalemuir seismic array (EKA) without adversely impacting upon its operation. In June 2014, a report was prepared by Xi Engineering Consultants with the full cooperation and significant input from the Ministry of Defence[30]. The report builds on initial Phase 0 work which identified that the current budget over estimates 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

[29] 'Environmental Noise Guidelines for the European Region, World Health Organisation, 2018

[30] "Seismic vibration produced by wind turbines in the Eskdalemuir region. Release 2.0 of Substantial Research project" prepared by Xi Engineering Consultants Ltd, Document Number FMB_203_FINAL_V5R, 15th June 2014

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.

10.2.44 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[31]. 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".

10.2.45 The authors further state 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".

10.2.46 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 wind farm.

Aerodynamic Modulation

10.2.47 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[20]. However the aforementioned DTI report[5] 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).

10.2.48 In December 2013, the wind industry trade association, RenewableUK, published detailed new scientific research[32] 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.

10.2.49 The Chairman of the IOA Noise Working Group said of the study:

"This research is a significant step forward in understanding what causes amplitude modulation from a wind turbine, and how people react to it."

[31] 'Wind Turbine Sound and Health Effects - An Expert Panel Review' W.D. Colby et al, 2009

[32] 'Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effects', RenewableUK, 2013, www.renewableuk.com

10.2.50 The RenewableUK 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"[33]. 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.

10.2.51 The authors state that:

"This shows that effective mitigation of AM on operational turbines is technically feasible."

10.2.52 The other notable outcome of the RenewableUK 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.

10.2.53 The IOA created a dedicated AM Working Group to undertake the further testing and validation recommended. A discussion document[34] 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[35], 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.

10.2.54 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[36], 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.

10.2.55 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. It should be noted that this is in addition to any penalty for tonal noise.

10.2.56 There are no standard or agreed methods, however, 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 particular turbine designs and/or dimensions for example.

10.2.57 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

[33] "Measurements to assess the effectiveness of turbine modifications to reduce the occurrence of AM in the far-field", Bullmore & Cand, Hoare Lea Acoustics, EWEA Technology Workshop: Wind Turbine Sound 2014, Malmo, Sweden, 9-10 December 2014

[34] Institute of Acoustics, IOA Noise Working Group (Wind Turbine Noise), Amplitude Modulation Working Group, Discussion Document, "Methods for Rating Amplitude Modulation in Wind Turbine Noise", April 2015

[35] Institute of Acoustics Noise Working Group, A Method for Rating Amplitude Modulation in Wind Turbine Noise, 9 August 2016

[36] WSP Parsons Brinckerhoff, Wind Turbine AM Review, Phase 2 Report, August 2016

required to ensure any proposed condition for a particular proposal met the necessary policy guidance tests.

Wind Turbine Syndrome

10.2.58 The condition proposed by paediatrician Dr Nina Pierpont in her report 'Wind Turbine Syndrome: A Report on a Natural Experiment' cites a range of physical sensations and effects as being caused by living near a wind farm[37]. This study is based on a series of interviews comprising a study group of 10 families. It is a self-published report with none of the research being published in any peer reviewed medical journal.

10.2.59 In a NHS response to the Pierpont report, a report titled 'Are wind farms a health risk?' states that there is no conclusive evidence that wind turbines have an effect on health or are causing the set of symptoms described as 'wind turbine syndrome'[38]. It was noted that the group study by Pierpont was not sufficient to grant the claims stated.

10.2.60 The aforementioned report 'Wind Turbine Sound and Health Effects - An Expert Panel Review'[31], 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".

10.2.61 The report went on to say:

"There are no unique symptoms or combinations of symptoms that would lead to a specific pattern of this hypothesized disorder."

10.2.62 An independent review of the state of knowledge about the alleged health condition was carried out[39]. This report 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 patho-physiological effects of wind turbine noise.

10.2.63 A paper 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[40]. It was concluded that there is no consistent association between wind turbine noise exposure and the symptoms associated with Wind Turbine Syndrome.

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[37] 'Wind Turbine Syndrome - A Report on a Natural Experiment', Pierpont, K-Selected Books, 2009

[38] 'Are wind farms a health risk?', NHS, 2009, www.nhs.uk

[39] 'Wind Turbine Syndrome (WTS) - An independent review of the state of knowledge about the alleged health condition', RenewableUK, 2010, www.bwea.com

[40] 'Health aspects associated with wind turbine noise—results from three field studies' Pedersen, Noise Control Engineering Journal, Volume 59, Issue 1, 2011

10.2.64 A study conducted by Simon Chapman, Professor of Public Health at Sydney University, provides evidence that noise and health complaints about wind turbines are psychogenic[41]. 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 spatio-temporal 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".

10.2.65 Therefore, in accordance with this literature and studies detailed above, it is not considered appropriate or relevant to undertake any assessment in relation to Wind Turbine Syndrome in relation to the proposed wind farm.

Wind Turbine Noise and Associated Health Effects Studies

10.2.66 In 2014 Health Canada released its findings from the "Wind Turbine Noise and Health Study"[42]. Health Canada, in partnership with Statistics Canada, conducted the study between residents of southern Ontario and Prince Edward Island where there were a sufficient number of 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.

10.2.67 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.

10.2.68 Health Canada broke the findings into five parts: illness and chronic disease, stress, sleep, annoyance and quality of life and noise.

10.2.69 Under Self-Reported Illnesses and Chronic Diseases, Health Canada states:

"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)".

10.2.70 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.

"Self-reported stress, as measured by scores on the Perceived Stress Scale, was not found to be related to exposure to WTN levels".

10.2.71 For Self-Reported Sleep:

[41] 'Spatio-temporal differences in the history of health and noise complaints about Australian wind farms: evidence for the psychogenic, communicated disease hypothesis', Chapman et al, University of Sydney, 2013

[42] "Wind Turbine Noise and Health Study: Summary of Results", Health Canada, November 2014, http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php

"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".

10.2.72 However, the study states, while some people reported some of the aforementioned health conditions, their existence was not found to change in relation to exposure to wind turbine noise.

10.2.73 An association was found, however, 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 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".

10.2.74 Lastly, under noise, 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.

10.2.75 A review conducted by McCunney et al in[43] November 2014, 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. Also addressed were specific components of noise associated with wind turbines such as infrasound and low-frequency sound and their potential health effects.

10.2.76 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?
- 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?

[43] "Wind Turbines and Health: A Critical Review of the Scientific Literature" McCunney et al, Journal of Occupational & Environmental Medicine, November 2014

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

10.2.78 The findings of the review are summarised thus:

- 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.
- 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.

10.2.79 The WHO's Environmental Noise Guidelines[29] 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.

10.2.80 The day-evening-night level (L_{den}) is an annual average L_{eq} 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_{90} 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.

10.2.81 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.