6th June 2016 **Reference No 4038P019901**

Heckington Fen Wind Farm
S36 Variation Application

by

Ecotricity

to

The Department of Energy & Climate Change

for

up to 22 Wind Turbines with a increased rotor diameter of up to 103 m whilst retaining consented tip height of 125 m

Wind Turbine Noise Impact Assessment Appraisal

by

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Commissioned and funded by local communities comprising:

Heckington Parish Council
South Kyme Parish Council
Amber Hill Parish Council

Supported by:

Holland Fen with Brothertoft Parish Council
Swineshead Parish Council
Great Hale Parish Council

Local residents supported by:

Heckington Fen Wind Turbine Action Group
Secretary, Heck Off
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Appendix:

Enercon EN82 2.3 MW wind turbine specification

Blue background indicates quotation from planning guidance, appeal decisions, standards and papers from learned journals. Pink background indicates quotation from application documents and their appendices.

Footnotes are superscripted; references are in [square parentheses].

1 Introduction

1.1 About the Author

1.1.1 I am John V Yelland MA DPhil (Oxon) MInstP FIET AMASA MIOA; I am an independent consultant with experience in many areas of acoustics and physics. My earliest encounter with acoustics was in the course of research into the high frequency acoustic impedance of liquid helium three for my doctoral thesis at the Clarendon Laboratory, Oxford University, over 45 years ago. My latest is in research into the low frequency acoustic emissions of wind turbines.

1.1.2 I have worked in senior research and development positions in and for large and small companies in the UK and Europe. I was founder of Milmega Ltd, a high technology company on the Isle of Wight, and its Chairman and Managing Director for 12 years.

1.1.3 I have been elected to corporate membership of the Institute of Physics and its offshoot the Institute of Acoustics. I have been directly elected by invitation to fellowship of the Institute of Engineering Technology. I am also an associate member of the AMASA.

1.1.4 I am principal acoustic consultant to the UK Independent Noise Working Group currently investigating the amplitude modulation (AM) of wind turbine noise and reporting to Parliament and Government.

1.1.5 Although I have many years of experience in the above fields I believe that the rigorous application of the principles of good science, and an in depth understanding of the mathematics that this requires, are the most important attributes when acting as a wind farm noise consultant. I prefer to offer transparent and accessible evidence to support my findings rather than offer bland assurances of my “professional judgement”.

1.1.6 When I am approached by prospective wind farm neighbours I undertake a preliminary noise impact assessment before representing them, which I decline to do if I consider that the developer’s NIA complies with current planning guidance. This may explain my high success rate in defending wind farm neighbours concerned by planning applications and appeals. I also advise District and Parish Councils.

1.2 About the Application

1.2.1 I have been commissioned by the parties listed on the cover of this document to examine perceived inadequacies in the operational noise impact assessments (NIAs) submitted by Ecotricity Ltd (previously trading as Next Generation Ltd, and referred to hereinafter as the applicant, which term includes any legal person contracted to or employed by the applicant) to DECC and North Kesteven District Council (the Council) as a part of planning application ref. no. 15/0416/S36 for a S. 36 Variation of Consent for Heckington Fen Wind Farm.

1.2.2 This is an unusual case in that the applicant seeks to vary an existing consent in order to install wind turbines which differ from those already consented, not just in manufacturer but also in their significantly greater physical dimensions and electrical generation capability. To determine the operational noise implications of the variation I have therefore reviewed the applicant’s original noise impact assessment (ANIA1) [1] as well as the revised version thereof (ANIA2) [2] submitted with the variation application.

1.2.3 As the installed power of the turbines exceeded 50 MW the application was determined by DECC, via a Public Inquiry held on 31st July 2012 by Planning Inspector Philip Major who had been appointed by the then Secretary of State for Energy and Climate Change Ed Davey.

1.2.4 The Inspector states in §288 of the Decision Letter (ref. DPI/R2520/12/8) that:

"The predictions of noise immission to the receptors around the site are such that it is expected that the noise limits recommended in ETSU-R-97 would be comfortably met. I have no reason to doubt that."

In fact the minimum headroom[1] predicted by the applicant in ANIA1 is just 0.3 dB (Chapter 10: Noise, table 10.10 on page 10.10). Whilst this does meet the ETSU limit it certainly does not meet it *"comfortably"*, a description which implies several dB[2] rather than a few tenths of a dB.

1.2.5 The Council's Committee Report [3], at page 39 of its Appendix, observes four deficiencies in the applicant's background noise survey (BNS), with which I concur, then states:

"The EHO has therefore advised that he is not in a position to assess the reliability of the baseline measurements and therefore agree prevailing background noise levels, both of which form the basis of the assessment and the determination of site specific noise limits."

The EHO proposed resolving those deficiencies by planning conditions, with which I do not concur, for two reasons.

(i) There are many other more serious, more complex and more subtle deficiencies in ANIA1 & 2, which no Council, because of the combined range and volume of any EHO's workload, could reasonably have been expected to detect without the help of an independent expert acoustician.
(ii) There is little purpose in setting a noise condition which the proposed wind farm may be unable to meet. This view is supported by appeal decisions cited in §4.3.3 below.

1.3 The Proposed "Variation"

1.3.1 The Proposed variation is in truth a major design change. The increase in swept area of the rotor to 58% more than that of the Enercon E82 specified in and consented for the original application is clearly not a minor material amendment. It is a major amendment, intended to significantly increase electrical power generation, which is a benefit, but a benefit which comes at the cost of a greater visual impact and, more importantly, a disproportionate increase in noise generation.

1.3.2 Under a previous administration DECC produced guidance in this matter [4], albeit with little mention of wind energy:

"26. The key point to note is that the variation procedure is not intended as a way of authorising any change in a developer's plans that would result in development that would be ***fundamentally different in*** *character or* ***scale*** [my emphasis throughout] *from what is authorised by the existing consent. Such changes should be the subject of a fresh application for consent in the form of a development*

[1] "Headroom" is the margin between a predicted immission noise level and the derived
[2] 2 dB is the minimum change in sound power level detectable by the human ear.

> *consent order under the 2008 Act or (offshore between 1 and 100MW) a section 36 consent.*
>
> *… … …*
>
> *Changes in the design of generating stations which have been consented but not constructed which would allow them to generate an amount of power that would be inconsistent with the original consent are likely to be appropriate subject matter for a variation application, **provided there are no major changes in the environmental impact of the plant."***

The 58% increase in rotor swept area is a fundamental rather than a minor increase in scale. The effect on environmental impact of such an increase is simply that a wind farm design deemed to emit noise at a level compliant with ETSU with minimal headroom would become significantly non-compliant with ETSU.

1.3.3 The benefit of the increased generation cannot be weighed in a planning balance against the cost in increased noise when the latter crosses an absolute threshold by exceeding ETSU noise limits; harm to health has no place in any planning balance.

1.3.4 I will show that my investigation of ANIA1 and ANIA2 found that even the original wind farm design would certainly have produced noise levels well in excess of ETSU limits. The proposed variation of the wind farm design would significantly increase that excess and, more seriously, would greatly increase the levels of so called "excessive amplitude modulation" (EAM).

1.3.5 In two conjoined appeals [5] for three wind turbines on Land at Crimp near Morwenstow the appellant sought in appeal A to increase both the rotor diameter and the tip height of the turbine, and in appeal B to increase the rotor diameter but decrease the hub height in order to maintain the tip height unchanged. Presumably the two appeals were lodged because one of them offered the option of an unchanged tip height and consequently no change in visual impact, on the somewhat questionable assumption that visual impact is determined entirely by tip height and not at all by rotor diameter.

1.3.6 Both appeals were dismissed. Having cited two High Court decisions, the Inspector states:

> *"This leads me to the conclusion that the proposed changes amount to a **fundamental alteration of the original planning application** and cannot be dealt with by way of a s73 application. The applications and subsequent appeals are therefore invalid and I can take no further action in the matter. Because of this, matters such as environmental impact assessment and **the planning merits of the appeal do not fall to be considered**."*

The changes of scale proposed in the Crimp appeals were far smaller than that proposed in the present case.

1.3.7 Ecotricity are not alone in seeking stubby tower variations; several developers, seemingly oblivious of the phenomenon of wind shear, are pursuing a similar objective: the fitting of larger rotors on to "stubby towers"[3], in order to maintain the same tip height, presumably in the knowledge that a section 36 application which increased the turbine tip height would be extremely unlikely to gain consent.

1.3.8 The stubby tower however, because of wind shear, not only greatly increases the incidence of EAM (v.i.), but also fails to deliver the full generation potential of the

[3] A term first used in by the wind industry lobby organisation RenewableUK [19].

larger rotor, because most of the additional area swept by the blades is very close to ground level and therefore in an area of relatively low wind speed.

1.3.9 It is most unfortunate that concern about the aesthetically harmful visual impact is causing an increase in the physically harmful noise impact and also reducing the renewable energy benefit in these stubby tower variation applications.

2 ETSU-R-97 and the IOA Good Practice Guide

2.1 Introduction

2.1.1 This section is purely explanatory and makes no comment on the technical content of the applicant's NIAs. Its purpose is to provide the technical background essential to an understanding of the sections that follow.

2.1.2 For the variation application to succeed it must comply with both ETSU-R-97 [6] (ETSU) and the Institute of Acoustics Good Practice Guide thereto [7] (the IOAGPG). The original consent (published February 2013) post-dates the consultation edition of the IOAGPG (published July 2012) but pre-dates DECC's endorsement of it (May 2013). The variation application post-dates both ETSU and the IOAGPG.

2.1.3 The good practice defined by the IOAGPG when it was published in May 2013 was of course just as much good practice when the original consent was granted three months earlier by DECC in February 2013. It therefore follows that the variation cannot now receive consent if the resulting wind farm would not comply with both ETSU and the IOAGPG.

2.1.4 In §2.2 - §2.4 below the ETSU procedures required for all large onshore wind turbine NIAs are summarised.

2.1.5 In §2.5 amplitude modulation, and particularly the phenomenon that has come to be called excessive amplitude modulation, are described.

2.2 The ETSU procedures

2.2.1 There are two procedures, referred to as "standard" and "simplified", prescribed in ETSU for assessing the impact of wind turbine noise on wind farm neighbours.

2.2.2 ETSU states that the procedures are intended:

"to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities".

2.2.3 The ETSU standard procedure is complex; it requires synchronized measurement of wind speed (up to 12 m/s), wind direction, rainfall, background noise and time, usually at more than one location, over a period of several weeks. This is followed by considerable data processing and calculation.

2.2.4 The ETSU simplified procedure imposes more constraint on the wind farm design, but offers a lower cost for the developer. The level of protection which the simplified procedure offers wind farm neighbours is at least equal to that of the standard procedure. The background noise survey of the standard procedure is not necessary, but a site visit is still required to ensure that all turbine setback distances[4] are correctly determined and to assess the current terrain and site conditions.

[4] Distances between turbine and homes.

2.3 The Simplified Procedure

2.3.1 The ETSU simplified procedure just applies an absolute 35 dB LA90[5] predicted turbine immission[6] noise limit at all times and at all wind speeds up to 10 m/s. This obviates the need for a background noise survey and thus greatly reduces the complexity of the NIA.

2.3.2 All wind farm NIAs start with the simplified procedure, which is essentially the creation of a noise map with a 35 dB LA90 contour. If there are no receptors within this contour the standard procedure is unnecessary. If there are receptors within it they must be assessed using the standard procedure, whereas those outside have already been predicted to meet the requirements of the simplified procedure.

2.4 The Standard Procedure

2.4.1 The ETSU standard procedure imposes relative rather than absolute limits on turbine noise; at nearby homes it must not exceed, except as noted below, the measured background noise by more than 5 dB at any wind speed [7] up to 12 m/s. Background noise surveys are a major part of any ETSU wind farm NIA that uses the standard procedure.

2.4.2 Both turbine noise and background noise increase with wind speed, but differently. As wind speed increases above 3-4 m/s turbine rotation starts and the noise rises fairly rapidly until at around 8-9 m/s wind speed (depending on the wind speed class of the turbine), above which the rotational speed, and thus the output power and noise power, of the turbine are constrained to remain fairly constant as wind speed increases further.

2.4.3 The background noise in rural environments is largely caused by vegetation – trees, hedges, crops etc. – moving in the wind, so it also rises with wind speed, slowly at first, then more rapidly with increasing wind speed. For homes near roads traffic noise will also contribute to (and sometimes dominate) the background noise, in which case there is little direct correlation between background noise and wind speed.

2.4.4 Figure 1, (from figure 3, page 16 of the IOAGPG), shows the background noise level typical of a quiet rural environment. Figure 2 is from the noise impact assessment for a location with relatively high background noise from surrounding trees and road traffic. Note how the wind speed versus immission noise plot curves upwards from the left, whereas the background noise trend line curves downwards from the right. The 5 dB relative limit is therefore most likely to be exceeded at moderate wind speeds, typically between around 4 and 8 m/s.

2.4.5 Background noise and wind speed measurements are averaged and recorded in synchronised contiguous 10 minute periods. Every ten minute period is plotted as a datapoint on a chart of wind speed, in m/s at 10 m reference height, against noise power level, in dB $LA_{90,\ 10\ min}$. A best fit logarithmic or polynomial curve is then fitted to the datapoints by a least squares computation.

[5] In reality a 37 dB LAeq limit,although described in ETSU and the IOAGPG variously as a 35 dB(A) and a 35 dB LAeq limit.

[6] The sound pressure level (i.e. noise level) at a receptor (i.e. home of wind farm neighbour).

[7] Here and elsewhere in this document wind speeds are referred to a standard measurement or prediction height of 10 metres above ground level unless stated otherwise. This is necessary because wind speed increases with height above ground level, a phenomenon known as wind shear.

2.4.6 If a polynomial curve is used the IOAGPG proposes that only 2nd, 3rd or 4th order should be used. In the interests of transparency it is good practice, and requires very little effort, to show all three. This is because the different orders can differ at critical wind speeds by several dBs, as seen in figure 2; obviously a precautionary approach requires that the order giving the lowest noise value be selected.

2.4.7 The best practice for the curve fitting process is to follow ETSU, pages 147 et seq., and use the logarithmic curve proposed there:

$$L_{pb}(V) = 10 \log (10^{A/10} + 10^{(B+C \log V)/10})$$

"This curve has been derived by assuming the background noise is made up of a fixed level which does not vary with wind speed plus a contribution from wind-induced sources whose sound power varies with V^x. Curves of this form have the advantage that they tend to predict reliable levels for wind speeds at which no experimental data have been obtained."

The logarithmic curve has the considerable advantage of using parameters based on physical reality, whereas polynomials are mathematical abstractions that use coefficients which do not relate to any physical reality. Furthermore there can be no dissent about which degree polynomial to use, and there is no negative gradient as lowest and highest wind speeds are approached. Although the spreadsheet processing is a little more demanding than simply clicking on the inbuilt Microsoft Excel polynomials the logarithmic fit is both mathematically sound and unambiguous, to the extent that the IOAGPG has seen no need to offer further guidance on its use.

2.4.8 It is important to understand that every datapoint on a background noise chart corresponds to a real ten minute period when both wind speed and background noise level were at the values plotted. As a consequence of a high population density most wind farms in England are designed with very little headroom beneath the ETSU limit. For example the datapoint encircled red in the chart of figure 2 corresponds to a real ten minute period when the noise level permitted by the derived ETSU limit (blue curve) is in fact 14 dB, not 5 dB, above the background noise level. There are also datapoints, such as the one encircled green, where the ETSU limit is in fact just below, not 5 dB above, the background noise, but a 10 minute period during which turbine noise is 5 dB below a level deemed to be acceptable does not of course compensate a 10 minute period during which the noise level was 9 dB over that level.

2.4.9 The above observation is neither new nor recent; ETSU expounds it on page 147:

"If the allowable turbine noise level above the background noise level were 5dB and it is assumed the turbine noise is constant, then it would be expected that for 9% of the operating period of the wind farm, wind turbine noise levels may exceed the prevailing background noise levels by 10dB or more."

Thus curve fitting the ETSU way means that the differential between turbine noise and background noise may well average 5 dB, but for any given 10 minute period it varies in the example of figure 2 between about 0 and 14 dB. Ten minutes of inaudibility does not compensate for ten minutes of excessive noise, but as approximately half of the datapoints are below the fitted curve, half of the time the turbine noise will be more than 5 dB above background and half the time it will be less than 5 dB above background.

The background noise level in the quietest rural locations is less than $LA_{90,10min}$ = 20 dB[8] at low wind speeds. ETSU considers that, however low the background noise is, 35 dB LA90 or less of turbine noise is unlikely to cause annoyance.

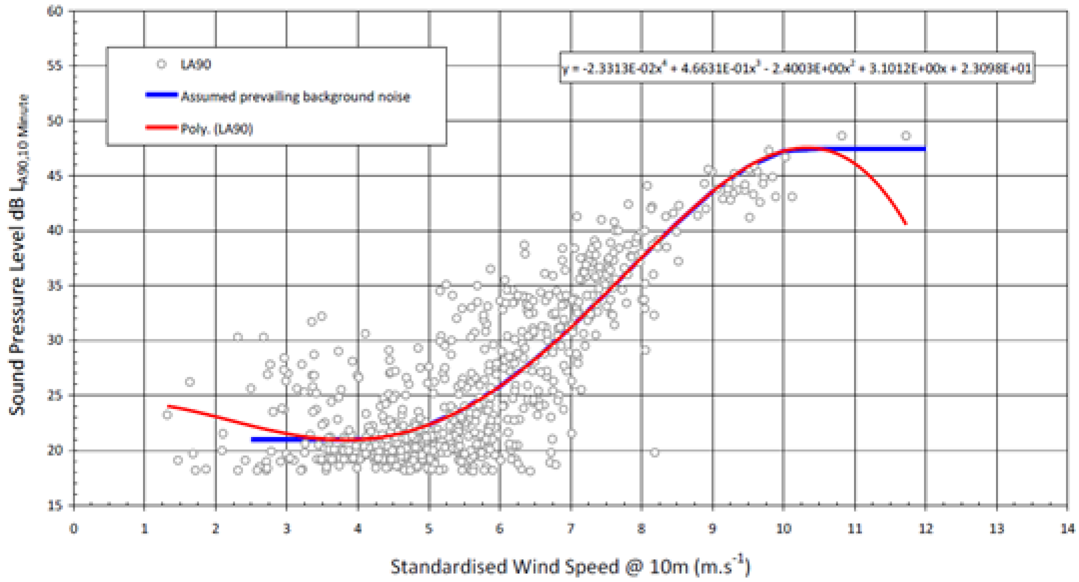

Figure 1: Noise scatter plot for a quiet but leafy rural location (from the IOAGPG). Note the electronic "noise floor" clearly visible at around 18 dB LA90.

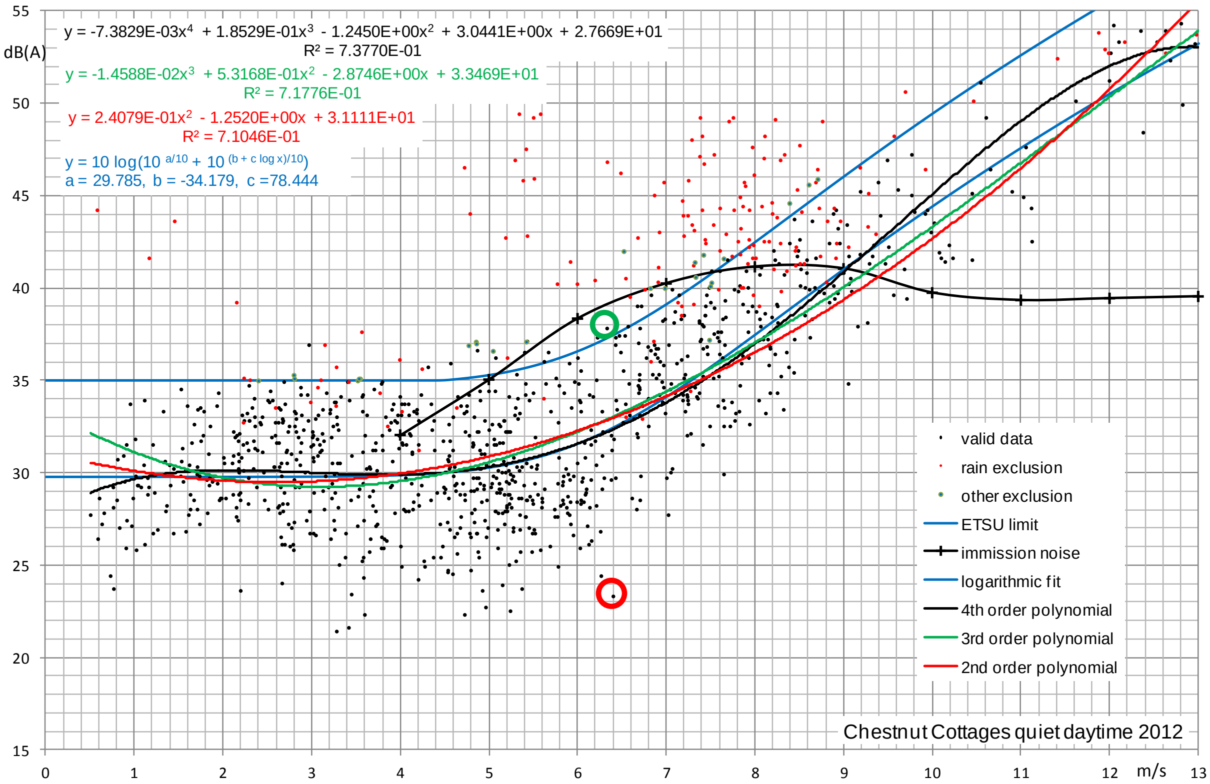

Figure 2: ETSU/IOAGPG advised background noise curves fitted to the noise data from a location with significant levels of traffic noise and within a forest.

[8] ETSU uses the $LA_{90,10\ min}$ descriptor (see §9, page viii, therein) which, there and here, is often subsumed into just dB(A).

2.4.10 ETSU therefore defines the maximum permitted turbine noise level in the external amenity area of a dwelling to be the greater of 35 dB(A) and 5 dB above the background noise level, rather than simply 5 dB above background noise level, at all wind speeds up to 12 m/s.

2.4.11 The above lower limits apply during evenings (1800 to 2300 hrs local time) and during weekend daytime (1300 to 1800 hrs on Saturdays and 0700 to 1800 hrs on Sundays). These times are referred to as ETSU quiet daytime, although it is essentially just evenings and weekends. The lower limit during ETSU night time (2300 to 0700hrs) is set at 43 dB(A), on the premise that there would be 8 dB of noise attenuation through an open window.

2.4.12 The noise limits for “financially involved” receptors can also be higher, with a limit of 45 dB(A)

3 Wind Shear and Amplitude Modulation

3.1 Introduction

3.1.1 Planning guidance has long remained silent on the matter of amplitude modulation, (AM) which in itself is of great concern. There is abundant and increasing evidence that a particular characteristic of wind turbine noise, somewhat misleadingly referred to as “excessive amplitude modulation” (EAM, or elsewhere sometimes OAM, “other amplitude modulation”), is seriously affecting the health of a significant minority of wind farm neighbours, of the human and other species, in this country and in many others. Its causes and effects are now fairly well understood. It is not a cause for concern at all wind farms; it shows dependence upon terrain, turbine model and local weather conditions, and of course primarily on the separation distance between turbines and homes. It is alluded to briefly in ETSU and scarcely at all in the IOAGPG.

3.1.2 Because EAM is an unpredictable but not uncommon phenomenon it is unrealistic to seek its control by a complaint driven planning condition. RenewableUK, the wind industry trade and lobby association, has proposed a template AM condition, but I support the decision of my Institution (the IOA) not to endorse it, as it does not provide the protection claimed of it and greatly complicates and obfuscates what in reality is a relatively simple measurement task.

3.1.3 I also endorse the statement of one of my other Institutions, the Acoustical Society of America, that serious and urgent work remains to be pursued in this area:

> **Acoustical Society of America**
> **Policy Statement**
>
> **May 2014**
> **Wind Turbines**
>
> Acoustic emissions of wind turbines include airborne, underwater, infrasonic, and structure borne sounds, and have been reported by individuals living near these facilities. Wind turbine acoustic emissions and their potential effects should be investigated and fully addressed in an interdisciplinary manner. The Acoustical Society of America urges that guidelines for relating wind turbine sound descriptors to probabilities of adverse effects be developed, to aid in wise wind energy planning. Methods for measuring and quantifying wind turbine acoustic emissions, particularly at very low frequencies, should be developed that support the interdisciplinary findings.

The Acoustical Society of America is internationally recognised as a, if not the, leading professional academic instruction concerned with acoustics, and maintains the highest standards of integrity and independence.

Dr Paul Schomer is a Fellow of the Acoustical Society of America and a Board Certified Member of the Institute of Noise Control Engineering of the USA.

The Acoustical Society of America (ASA) is the premier international scientific society in acoustics devoted to the science and technology of sound. Its 7000 members worldwide represent a broad spectrum of the study of acoustics. ASA publications include the Journal of the Acoustical Society of America--the world's leading journal on acoustics, Acoustics Today magazine, books, and standards on acoustics. The Society also holds two major scientific meetings per year. For more information about the Society visit our website, http://www.acousticalsociety.org Dr Schomer

3.1.4 It happens that the present variation application, because it proposes a "stubby tower" turbine geometry, is a prime candidate for EAM, as is explained in detail in §3.2 and §3.3 below.

3.2 Wind shear and sound propagation

3.2.1 An understanding of wind shear and EAM is essential in order to understand the "stubby tower" problem.

3.2.2 The difference between upwind and downwind sound propagation is not due to the sound being "blown by the wind"; how could it be when the speed of sound is about 50 times the wind speed in a moderate breeze? The difference in fact is due to refraction caused by wind shear. Figure 4 on page 16 of the IOAGPG provides a something of a caricature of the phenomenon. It is not of course a recent discovery; for a clear and accessible description of refraction caused by wind shear I recommend Professor Gabrielson's article [8] in "Acoustics Today", published by the ASA (Acoustical Society of America). Figure 3 below reproduces an illustration therein adapted from the papers of Professor Osborne Reynolds published by the Royal Society in the 19th Century [9].

Figure 3: Wind shear,with upward and downward refraction upwind and downwind respectively, as illustrated by Professor Osborne Reynolds circa 1876.

3.2.3 Wind direction and wind shear are indicated in figure 3 by the early Victorian meteorological mast. The upwind and downwind propagation paths curve upwards and downwards respectively, increasing the downwind noise level whilst decreasing the upwind noise level, the latter to the extent and a "noise shadow" is created at some distance from the electric bell. But this "steering" of the sound is a gradual process, because of the orders of magnitude difference between speed of wind and speed of sound. The upwind sound reduction caused by refraction due to wind shear is therefore not significant until some distance from the source, particularly when the source is of the height of a wind turbine.

3.2.4 The refraction occurs because the wind speed is add/subtracted to the speed of the sound propagating downwind/upwind. This distorts the wavefront as Professor Reynolds illustrates in figure 3; because sound propagates in the direction perpendicular to the wavefront this also affects the direction of propagation as shown by the two black lines. In Professor Reynolds' own words:

> *"when sound proceeds in a direction contrary to that of the wind, it is not, as had been thought, destroyed or stopped by the wind, but that it is lifted, and that at sufficiently high elevations it can be heard to as great distances as in other directions, or as when there is no wind—thus confirming the hypothesis first propounded by Professor Symms and afterwards by myself, that the effect is owing to the retardation of the velocity of the wind near the earth, which allows the sound moving against the wind to move faster below than above, and thus causes the fronts of the waves to incline upwards, and consequently to move in that direction."*

3.2.5 Whenever there is wind there is wind shear. Contact of the moving air with the ground creates turbulence and reduces the wind speed, which approaches zero as ground level is approached. The amount of wind shear is dependent on atmospheric conditions and on the "roughness length" of the ground, from low over ice or smooth water to high over city landscapes.

3.2.6 Nocturnal temperature inversion (temperature increase with altitude) is responsible in itself for a small amount of downward refraction due to the inverse dependence of atmospheric density on altitude. The main effect of nocturnal temperature inversion on wind turbine noise however is doubly indirect; the stable atmosphere increases the wind shear and the increased wind shear causes greater EAM.

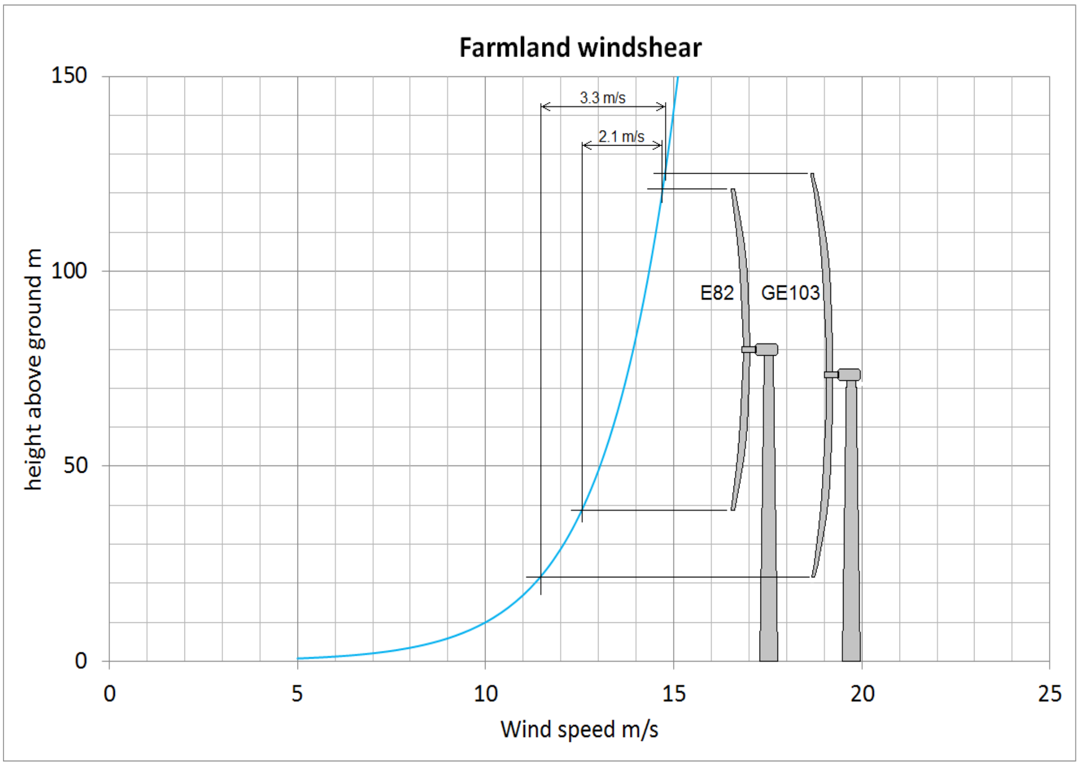

Figure 4 Effect of a "stubby tower" on windshear.

3.2.7 The chart in figure 4 shows, to scale, the vertical variations in wind speed (i.e. the wind shears) over the rotor disc of the originally proposed E82 turbine (2.1 m/s) and the currently proposed GE103 turbine (3.3 m/s, 57% more than for the E82 turbine). A 10 m/s wind speed at 10 m reference height wind speed is assumed, with a roughness length of 0.05 m, as quoted in ETSU-R-97 for *"farmland with some vegetation"*. This value however is based on measurements made during normal working hours, when wind shear is least. As noted above, after sunset wind shear can be much greater. I will now explain why high wind shear implies high levels of low frequency wind turbine noise.

3.3 Amplitude Modulation

3.3.1 All operating aerofoils produce aerodynamic noise. AM describes the 2-3 dB periodic variation at the blade pass frequency in the level of aerodynamic noise emitted by a wind turbine, which can be quantitatively explained by the rotation of the blades causing a periodic change of distance between blades and observer (i.e. listener). It is usually described as being due to the Doppler effect and convective amplification. More correctly, the Doppler effect refers to a frequency change, not an amplitude change, but is certainly accompanied by an amplitude change, which can be visualised as due to the sound energy being delivered a little faster in the direction of movement and more slowly in the opposing direction.

3.3.2 EAM can be qualitatively explained [10] by high wind shear. Although the pitch of wind turbine blades can be adjusted in order to suit the wind speed and power requirement from the generator it cannot be adjusted anywhere near quickly enough to maintain optimum performance within a rotation cycle, so it is adjusted for optimum performance at around the hub height wind speed. This means that at blade zenith (i.e. blade vertically upwards) the blade is moving too slowly to maintain the angle of attack below its stall value. When the blade does stall the airflow on the leeward side of the blade changes from laminar to turbulent, with a consequent increase in the aerodynamic noise amplitude (around 3 dB) and about an octave decrease in its frequency. Modern turbine blades are flexible, so the sudden loss of wind lift when in stall causes the blade to flex and rebound at its resonant frequency, typically in the region of 1 Hz, producing high levels of infrasound at that frequency, particularly when it is close to the blade pass frequency (BPF) or a harmonic thereof.

3.3.3 Although much of this very low frequency emission is, precisely because the frequency is so low, inaudible, the energy content is extremely high, as is seen in figure 18, which is a chart of independent measurements by the accredited international test house Windtest gmbh for RePower, the then manufacturers of the MM92 model wind turbine.

3.3.4 I have shown above that, in the matter of wind turbine noise impact, and with particular reference to so-called "excessive amplitude modulation" (EAM), decreasing the hub height can disproportionately increase the noise impact of a wind turbine. In general terms, any perceived reduction in visual impact achieved by reducing the hub height is seen to be much outweighed by the consequent increase in noise impact. Furthermore, whereas an adverse visual impact simply causes annoyance, an adverse noise impact can harm health as well as cause annoyance. Wind shear causes turbine noise to be increased disproportionately when turbine dimensions are changed from normal to "stubby tower" proportions.

4 Review of Applicant's NIAs

4.1 Introduction

My major noise concerns with the applicant's original project and ANIA1 are as follows:

(a) The wind farm design has the turbines too close together at nearly twice the maximum packing density recommended by Government Planning Guidance. This both increases the wind farm noise emission and decreases its electricity generation and mechanical reliability.

(b) The ETSU lower quiet daytime noise limit has been set at the maximum value of 40 dB LA90 with no satisfactory explanation to justify this limit. Since DECC's endorsement of the IOAGPG May 2013 it has not been in the gift of the developer or its acoustic consultant to deviate from 35 dB LA90.

(c) The microphone positions used in the background noise surveys were not fully compliant with ETSU or the IOAGPG at any of the six BNS locations

(d) The receptor with the minimum turbine separation distance and the maximum predicted noise level was assessed with an inappropriate proxy and an incorrect grid reference.

(e) Inappropriate proxies were used for assessment of receptors where no BNS was undertaken.

(f) Separation distances from turbines overstated by measuring to arbitrary points within receptor amenity areas rather than to the closest part of amenity area as defined in ETSU; see IOAGPG §4.3.8:

> *"Calculations should be made at points representative of the relevant outdoor amenity area (as defined in ETSU-R-97)* ***at locations nearest to the proposed wind farm development."***

4.2 Wind Farm Design in Respect of Noise: Turbine Spacing

4.2.1 The proposed turbine positions are unusually closely spaced; planning guidance (EN3) proposes 4D x 6D (crosswind x downwind, where D is the rotor diameter). With the proposed 103 m rotor diameter, downwind spacings around 450 m and crosswind spacings around 300 m the guidance proposal of 4D x 6D has been abandoned in favour of 2.9D x 4.4D, a turbine density 1.9 times that of the recommended spacings. There are two consequences of this; the mean wind farm output power is significantly reduced, which does not concern me here, but the turbine noise emission power is significantly increased, due to inflow turbulence, which does concern me here.

4.2.2 The reason that the UK Government Planning Portal advises the 4D x 6D spacing of figure 5 as a minimum is that a turbine operating in the turbulent wake of another has a lower electrical output and a higher noise output than a turbine in clean airflow. Whilst the 4D x 6D spacing is advised in EN3 rather than mandated, the increased inflow turbulence characteristic of closer spacings invalidates turbine manufacturer's operational noise warranties. Published generation and noise data, being based on measurements of single turbines, can no longer be relied upon. I have not allowed for this in my NIA, but I would expect some margin below the ETSU limit to be reserved to accommodate it.

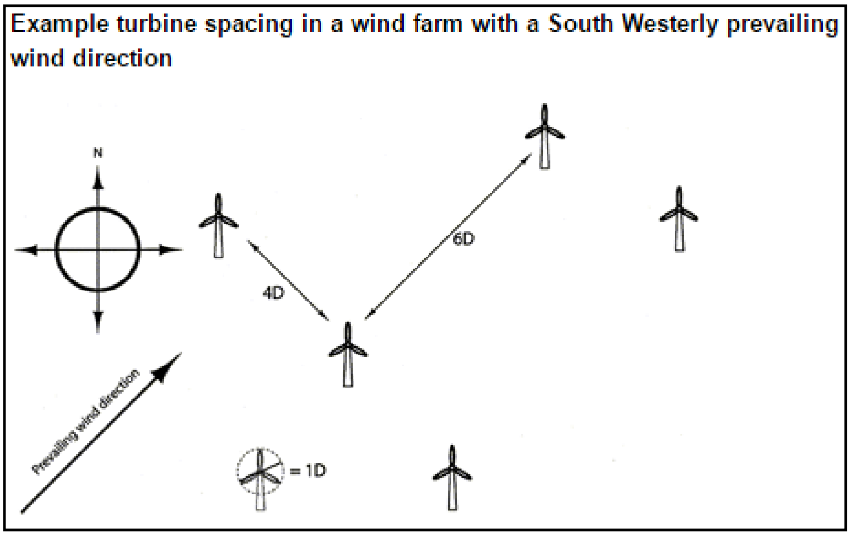

Figure 5: EN3 guidance on wind turbine spacing.

4.3 Wind Farm Design in Respect of Noise: Curtailment and Conditions

4.3.1 It is not best practice to design a wind farm, find its predicted noise level to be non-compliant, then to resolve the problem by curtailing the turbines to generate lower power and less noise. The ecologically and economically more appropriate solution is the use of smaller or fewer turbines.

4.3.2 I firmly believe that a well-designed wind farm should not include any element of curtailment in its design. When a wind farm gives rise to noise complaints and is subsequently shown to be non-compliant curtailment may seem to be a practical means of mitigation, but the wind farms where this is now occurring inspire little confidence in that thesis; as just three examples I quote Cotton Farm, Fullabrook and Kessingland wind farms.

4.3.3 Planning Inspectors Paul Griffiths [11] and Brian Cook [12] and PJ Asquith [15] each explain why noise conditions are not an appropriate solution to the uncertainty of turbine noise prediction in general or to the unpredictability of EAM in particular:

Appeal decision, Land North of A30, Summercourt, ref. APP/D0840/A/12/2189483:

"17. It could be argued that if the wind turbine operated in breach of the suggested condition, the Council could take action to ensure that it did. However, taking the issue of noise in isolation, there seems little sense in granting planning permission for a wind turbine subject to a noise condition that it may not be able to properly comply with. Such a condition might well negate the benefit of granting planning permission, thereby failing the test of reasonableness set out in Circular 11/957. Moreover, allowing that situation to come about might well lead to serial complaints, the need for further monitoring, shut down periods, and potentially, long-drawn out enforcement action. The resulting uncertainty would itself be detrimental to the living conditions of nearby residents."

Appeal decision, Chytane Farm, Newquay, ref. APP/D0840/A/14/2212162:

"29. The appellant does not dispute that wind turbine sound is amplitude modulated sound. The appellant's evidence is also that while there are several methods for the assessment of enhanced amplitude modulation proposed, no agreed method is as yet available. This is particularly the case in the UK where no agreed penalty system for amplitude modulation is in place. No party has therefore

suggested a condition that might be imposed to control what the appellant accepts is largely a matter of subjective and personal judgement when it comes to perceived annoyance.

30. In those circumstances it appears to me that there is no prospect of framing a condition which would ensure effective control of what the residents of Chytane Farm consider now to be an unacceptable impact upon their living conditions and what they consider would be an enhanced and cumulative effect if the appeal proposal goes ahead. I therefore consider that the appeal proposal would conflict with saved LP policies 10 and 37 which address the amenity of nearby residents and, in the case of LP policy 37, specifically states that development which would cause harm from noise will not be permitted. I note that the nature of my conclusion on this issue is consistent with that of my colleague who determined an appeal for a similar type of development on land to the north of the A30 at Summercourt (ref:APP/D0840/A/12/218943).”

Appeal decision, Westwood Farm, Ashover, ref. APP/R1038/A/14/2228756:

“22. It is suggested that in the event of permission being granted a detailed condition could be imposed which would provide protection for noise-sensitive receptors. This condition would trigger action in the event of verified complaints alleging noise disturbance. However, in a situation where there is a degree of uncertainty as to likely potential noise levels which could be at the margins of acceptability, the efficacy and reasonableness of such a condition must be in question.

23. I accept that the appellant has gone to considerable efforts to provide evidence to show that noise from this single turbine would not be an unduly disturbing feature for nearby residents. Nonetheless, on the basis of the evidence before me I am not convinced that it has been clearly demonstrated that the nearest residential receptors would (or could be) adequately safeguarded from disturbance from operational turbine noise which could be detrimental to their living conditions.”

4.3.4 At §9.30 in ANIA2 the applicant proposes curtailment of wind turbine power to reduce noise only during the ETSU daytime hours; curtailment is considered unnecessary at night because the ETSU lower fixed limit is then increased to 43 dB LA90. Yet the great majority of wind farm neighbours’ noise complaints relate to sleep deprivation at night; the proposed daytime curtailment would do nothing whatever to address these complaints.

4.3.5 There are two reasons why wind turbine noise is more problematic at night. Wind shear is usually greater at night, which reduces the downwind geometric divergence, and thus the downwind attenuation between turbines and receptors. More importantly, when stall-induced EAM occurs the very low frequency noise is not attenuated by the 8 dB assumed in ETSU[9] in passing through an open or even closed window.

[9] The difference between the quiet daytime 35 dB LA90 limit and the night time 43 dB LA90 limit.

5 The Background Noise Surveys of ANIA1

5.1 Introduction

5.1.1 The background noise surveys from ANIA1 were retained for ANIA2. Whilst I acknowledge that the original application was consented with these surveys I am concerned that, in spite of their apparent completeness and their excellent standard of presentation, they are seriously flawed, and should have been challenged in several respects before the original determination. I was initially moved to investigate the surveys simply because I found that some of the background noise levels reported by the applicant were unexpectedly high for what can only reasonably be considered as a tranquil rural environment.

5.1.2 It is most regrettable that the applicant has not responded positively to several residents' recent and repeated requests for the supply of the background noise and meteorological data used in ANIA1 and ANIA2. §2.2.8 of the IOAGPG states:

*"It is considered to be **good practice** to provide the noise and meteorological data available to the resident upon request."*

Failure to supply the data is therefore a failure to comply with the planning guidance of the IOAGPG as endorsed by DECC and its then Secretary of State Ed Davey.

5.1.3 Rain exclusion is claimed in all six Noise Monitoring Information Sheets (ANIA1 Appendix 10.C) *"when the rain gauge registered rain."* The 10 minutes contiguous monitoring periods before and after each period when rain fell should also have been excluded. There is no evidence of a rain gauge in any of the microphone photographs of Appendix 10.C, only the statement that *"The meteorological monitoring system had a rain gauge installed during the noise survey period; data from this gauge was therefore used to exclude those periods where rain was indicated."* This is a large wind farm with assessed neighbours spread over 5 km apart, so a single rain gauge would hardly have been adequate, particularly when the two contiguous periods around those periods with rain indication were not excluded.

5.1.4 Fortunately Met Office records show that there was very little rainfall in the area of the proposed development during the survey period.

5.2 Comparison of all Six Surveys

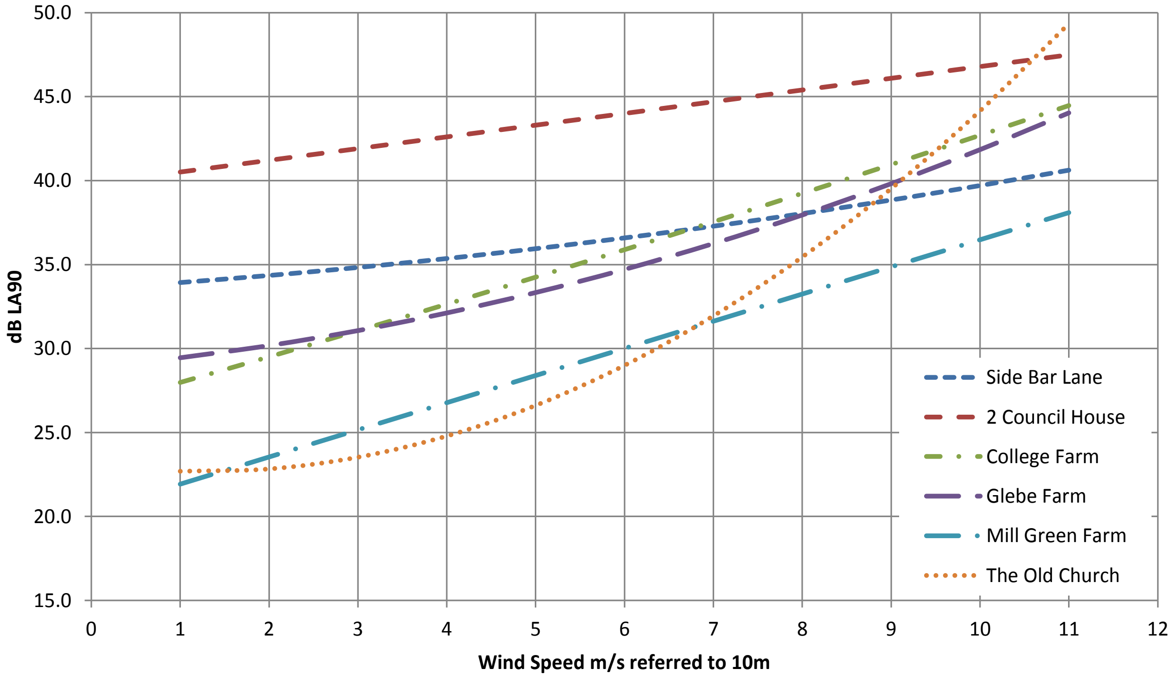

Figure 6: Applicant's derived backgound noise polynomials for all six background noise surveys.

5.2.1 In the absence of the applicant's raw noise data is instructive to compare the measured noise levels at the six surveyed receptors, plotted in figure 6 above from the applicant's chart polynomial coefficients. With the single exception of The Old Church there is relatively little increase (5 to 12 dB) in the background noise level from 4 m/s (cut in wind speed) to 11 m/s; at The Old Church however the increase is 25 dB. The reason for this is explained in §4.3 below; essentially it is because the chosen microphone position was too close to trees and hedges.

5.2.2 For the other five surveyed receptors there are clearly noise sources in play other than wind agitated trees, crops and foliage; one of these is the traffic on the A17, which is a legitimate part of the usual ambient background for those receptors close to it. Some others sources are atypical, and therefore not legitimate.

5.2.3 I now examine each BNS in the order in which they appear in ANIA1 table 10.2.

5.3 Background Noise Survey at The Old Church

5.3.1 The microphone position reported is in the far south-west corner of the plot, on an area of acoustically hard concrete tiles and adjacent to a water feature; I understand however that the resident made no use of the water feature during the BNS. The microphone position (see ANIA1) was also unnecessarily close to substantial evergreen trees to its south-east and east. Referring to figure 6 above, this would explain why the background noise measured here had the highest wind dependence of all six surveys; indeed it was the lowest of all six surveys at turbine cut in wind speeds but the highest at high wind speeds. The yellow spot in my figure 7 shows the applicant's chosen microphone position; the red spot shows an alternative position arguably quieter by a dB or more at sensitive wind speeds.

Figure 7: Yellow dot shows applicant's microphone position at The Old Church.
Red dot shows quieter alternative.

5.3.2 Apart from the preceding comments the applicant's use of this BNS as a proxy for the assessment of nearby Spinney Farm was appropriate. As Spinney Farm is set back further from the turbines, and thus has a 1.8 dB lower propagation attenuation prediction than is The Old Church, I consider this proxy use as acceptable.

5.4 Background Noise Survey at College Farm

5.4.1 The applicant states in §10.52 of ANIA1:

"The monitoring locations were also positioned as far as practically possible from any ***residential drainage systems*** *to minimise any associated noise influence."*

The microphone was in fact installed very close to a septic tank, the inspection cover and vent for which are clearly seen in all the applicant's own installation photographs C5 and C6 in ANIA1 Appendix 10.C. This may well – or may not – have added to the background noise.

5.4.2 The applicant states in ANIA1, §10.44:

"The sound level meters were generally located on the wind farm side of the property in question where possible, never closer than 3 m from the façade of the property and as ***far away as was practical*** *from obvious atypical localised sources of noise such as* ***running water, trees*** *or boiler flues."*

The red dots in figure 8 proposes entirely practical – and less noisy – microphone positions.

The applicants microphone position was within 3 - 4 metres of hedging (in autumn leaf) and trees (not in leaf) on both sides of the narrow end of the triangular garden plot, which explains the significant correlation of noise and wind speed in the background noise curve seen in figure 6 above, but does not explain either the

Figure 8: Yellow dot shows applicant's microphone position at College Farm. Red dots show quieter alternatives.

Figure 9: Caton House, omitted from ANIA1.

wide spread of data points on the background noise chart, nor the high ambient noise level given the tranquil rural environment clearly observed on several site visits. This could of course simply be due to the microphone position, or to College Farm being a busy working livestock farm, or indeed to a combination of both these sources; there is uncertainty here. Had the microphone been positioned as indicated by one of the red dots in figure 8 there would be less uncertainty.

5.4.3 This location was used as a proxy for Catlins Farm; it is not an appropriate proxy, as Catlins Farm is not a working farm. Moreover Caton House, a private residence on the western side of Brown's Drove, has its main amenity area facing the proposed turbines with a wide uninterrupted view towards all of them, yet this receptor has no mention in ANIA1. The residents were not approached by the applicant nor asked to host a background noise survey. The failure to notice Caton House is the more surprising as the only access route which the applicant can have taken to reach College Farm passes the entrance to Caton House, the most northerly of a group of three residences, and not difficult to see from the road; see figure 9. I understand the residents have written to DECC raising their concerns.

5.5 Background Noise Survey at 2 Council House

5.5.1 The A17 is the main road between Newark and King's Lynn, and is the dominant background noise source for those receptors bordering it. The applicant installed monitoring equipment to assess No. 2 Council House, which was also used as a proxy for seven other receptors bordering the A17. I understand that the resident at No. 2 Council House was told during installation that it was *"the perfect place for monitoring"*; it clearly was not, as the applicant's own photographs amply demonstrate (C9, C10 and C11 of appendix 10C of ANIA1). Indeed the applicant states in Appendix10.C:

"...the meter was positioned at approximately 2m from the building façade. It was decided to leave the meter at the rear of the property, as this location was more screened from noise generated by road traffic on the A17 than the front of the property."

The positioning of the microphone on the north side of the property is in fact required by ETSU, the IOAGPG, and indeed common sense, as the proposed wind farm position is to the north of the property. *"Approximately 2 m"* was in fact 1.8 m, **which is far from compliant with the minimum distances of 10 m, or 3.5 m in certain circumstances, required by ETSU,** page 84:

"In order to ensure that measurements of wind turbine noise are not influenced by reflections off buildings the microphone should be positioned at least 10m away from the facade. It may be appropriate to undertake background noise measurements closer than this if sheltered locations close to the property are most often used for rest and relaxation. Background noise measurements should not be taken closer than 3.5m from the facade. ***In circumstances where these conditions cannot be fulfilled an alternative location should be identified****…"*

and page 103:

"To achieve this [free field measurement conditions]*, the microphone should be placed at least 10m away from the building facade or any reflecting surface, where possible, and no less than 3.5m away where this is not possible* ***with appropriate adjustment made to measured levels to account for facade effects.****"*

5.5.2 There were in fact two acoustically reflective vertical façades at right angles, with additional reflected noise from the hard patio, and a washing line can even be seen the applicants photographs scarcely half a metre above the microphone. Furthermore the other adjacent Council Houses, although a similar distance from the A17, do benefit from the acoustic barrier formed by the trees and houses between the A17 and the slip road, whereas 2 Council House is right opposite the slip road junction with the A17.

5.5.3 In the Noise Monitoring Information Sheet for this receptor (appendix 10C page 10-5 of ANIA1, and repeated in the text of ANIA1 at 10.44) the applicant seeks to justify this choice of microphone position as:

"...due to the very small amenity area associated with this property and the need to avoid placing the meter in a position that obstructed the driveway".

I would ask why the applicant chose such an inappropriate receptor as a proxy for seven other assessed receptors, all of which could have accommodated the microphone well away from building facades, on lawn, and further from the A17. From site visits it has been ascertained that no residents of the other Council Houses, nor particularly of Ashleigh House, were approached or invited to host a BNS. The residents at Ashleigh House have also confirmed this fact to DECC.

5.5.4 In short the BNS at 2 Council Houses has no validity for the assessment of even 2 Council Houses, let alone for use as a proxy for other receptors, but I will nevertheless comment further upon two other aspects of this BNS: the applicant's wind directional filtering, and the applicant's extensive use of it as a proxy

Figure10: East Heckington village showing ● applicant's non-compliant microphone position at 2 Council Houses and ● proposed compliant position at Ashleigh House.

5.5.5 Wind directional filtering has been applied at this receptor. In the Side Bar Lane background noise charts of figures E1 to E4 of appendix 10E of ANIA1 all wind directions from East round to West have, quite properly, been excluded to reduce the effect of traffic noise from the A17. This technique is correctly explained by the applicant in ANIA1 §10.53, and also on page 16 of the IOAGPG. All four charts therefore show a large number of excluded points. In the case of Sidebar Lane the excluded points are at significantly higher noise levels than the included points; the objective of the wind directional filtering has therefore clearly been achieved.

5.5.6 In the case of 2 Council House however it is equally clear that the objective has not been achieved. The only obvious effect of exclusion of the datapoints from the northern compass quarters is that there are insufficient included points to meet the ETSU requirement (page 99) for coverage of wind speeds up to 12 m/s:

"It must be ensured that during the survey period wind speeds over the range zero to at least 12 m/s and a range of wind directions that are typical of the site, are measured."

This in itself renders the BNS invalid.

5.5.7 The applicant's exclusion of 90° to 270° wind directions is puzzling; 135° to 315° would have more accurately accommodated both the bearing of the wind farm from the two receptors in question and the orientation of the A17; however such an exclusion would have left just a single datapoint above 6 m/s on the ETSU night time charts and scarcely more on the ETSU quiet daytime charts.

5.5.8 The 2 Council House microphone position, at only 55 m from the A17, is too short a distance for significant upward refraction from wind shear. This is why directional filtering has had no significant effect for 2 Council Houses.

5.5.9 For the reasons given above, irrespective of the other defects of this BNS noted above, it is unsuitable for use as a proxy at any locations significantly more distant than is 2 Council Houses from the A17, because every doubling of distance reduces the traffic noise by approximately 3 dB. The adjacent table shows in red the four receptors where this applies.

Receptor	Distance from A17
2 Council Houses	55 m
Elm Grange Farm	152 m
Home Farm	250 m
Rakes Farm	250 m
Rectory Farm House	51 m
Six Hundreds Drove	50 m
Swineshead House	107 m

5.5.10 The applicant states in §10.44 of ANIA1 that:

"...this location was considered likely to result in a lower background noise level than alternative locations"

I profoundly disagree; the obvious choice for a BNS for this group of dwellings is Ashleigh house (see figure 10), where the amenity area is both further from the A17 and devoid of all the opportunities for background noise inflation presented by 2 Council Houses. Yet the residents of Ashleigh House, and indeed residents of the other Council Houses, assert that the applicant made no approach to any them to host a BNS.

5.5.11 For the avoidance of any doubt that the applicant's statement quoted above is disturbingly wrong I refer again to my chart of polynomials in Figure. This background noise survey is deeply flawed, and therefore invalid for 2 Council Houses itself. It is also invalid for use as a proxy for any of the other six of the receptors listed above, and would have been for four of them even if it had been correctly executed.

5.5.12 When the decision-maker for the present application visits the site he or she is urged to listen carefully to the background noise levels at the applicant's chosen microphone position at 2 Council Houses and immediately afterwards at the northern boundary of the amenity area of Home Farm in order to form a view on the relative background noise levels at these receptors.

5.6 Background Noise Survey at Side Bar Lane PROXY

5.6.1 My first concern here is the applicant's assertion in Appendix 10.C page 10.5 that:

"This monitoring location was selected to provide representative background noise levels from the properties towards the South end of Side Bar Lane. The meter was not located in the amenity space of a residential property ***as access permissions could not be agreed.****"*

Residents of Derwent Cottage and the other nine properties in that vicinity (excluding recently built Meadow View) have stated, and confirmed in writing to DECC, that they were in residence on and around the date of installation of the BNS equipment, **and were not approached to host it**.

Figure 11: Microphone position given by applicant's OS reference (+), with which I and residents concur.

Figure 12: My photograph from Derwent Cottage microphone position, view looking west, as this view was missing from applicant's views in ANIA1.

5.6.2 A further concern is the applicant's four microphone photographs (ANIA1 figures C13 to C 16), two of which look north and south. The other two look not **east and west**, as might be expected, but **north-west and south-east.** Had one looked west the vertical façade of a garage a few metres behind the microphone, shown in my figure 12, would have been seen. The garage is also visible in the aerial photograph of figure 13. **The microphone was not in the free-field position required by ETSU, because there was a vertical façade close behind it (estimated 3 m). I consider the applicant's microphone photographs to be highly misleading, as they avoided showing both the vertical façade and the chickens.** Figure 11 shows the microphone position plotted from the applicant's OS grid reference on a fragment of OS map.

5.6.3 Microphones at Side Bar Lane and 2 Council Houses were respectively 450 m and 55 m from the A17. These two receptors showed the highest noise levels, particularly at low wind speeds, and little correlation with wind speed, as would be expected when traffic noise dominates – or at least when wind does not dominate.

5.6.4 The A17 is a linear noise source[10], so even with no wind direction filtering one would expect about 9 dB less traffic noise from it at Side Bar Lane than at 2 Council Houses. At only 55 m the from the A17 the traffic noise level will have negligible dependence on wind direction, but at 450 m there would be several dB

Figure 13: Microphone position at Derwent Cottage PROXY.

[10] Noise from a linear source is attenuated by geometric divergence ("spreading") at 3 dB per doubling of distance,not by 6 dB per doubling as is the case for point sources.

more attenuation upwind compared with downwind, so 12 – 13 dB difference would be expected between A17 traffic noise measured at these two receptors. Side Bar Lane itself carries very little traffic; on Google mapping, photographed around midday, there are only two vehicles over the 3 km northwards of its junction with the A17. Thus the Side Bar Lane noise level is some 6 - 7 dB higher than would be expected; there was clearly some additional wind independent noise source recorded by the Side Bar Lane microphone.

5.6.5 The additional noise source was in fact a large brood (around 40) of free range chickens and two cockerels kept by the residents of Derwent Cottage. The placing of the microphone on the landowner's[11] field just a few metres from the chickens will have done very little to attenuate the noise from them. There is photographic evidence of the existence of these chickens, and witnesses (purchasers of the eggs) are available.

5.6.6 This BNS is therefore invalid for use as a proxy for adjacent receptors where there are no chickens, and now for Derwent Cottage itself, as the residents no longer have any chickens within their grounds as confirmed in their submission to DECC. It is surprising that chickens do not feature in the applicant's description of the noise environment, unless perhaps included in "birdsong".

5.7 Background Noise Survey at Glebe Farm

5.7.1 This BNS is problematic in that the written account of Mr Tutty, the owner of Glebe Farm, states that the positions of the microphones (there were two, not one as reported by the applicant), and of the dates of the survey, differed considerably from the positions and dates reported in the applicant's account in ANIA1 Appendix 10.C. Referring to figure 14 below, the applicant claims that a single microphone was in position "**O**". The resident agrees that a microphone was indeed photographed there, but asserts that it was then moved to position "**B**" for the duration of the BNS. A second microphone was installed in position "**A**".

5.7.2 The applicant's microphone photographs therefore have no relevance to the true microphone positions used for the BNS. Furthermore I understand directly from Mr Tutty that the microphones were both removed well before the dates stated in ANIA1 Appendix 10.C. I also understand that Mr Tutty was engaged in the movement of a large bank of earth with a mechanical digger close to positions "**A**" and "**B**" through much of the survey period. On enquiry he was assured by the installing technician that any noise due to the digger would be removed. Examination of the ETSU quiet daytime charts for Glebe Farm and for Five Willow Wath Farm shows that the very few excluded points on the former are also excluded on the latter, so the digger noise was clearly not removed.

5.7.3 I am also concerned by the unnecessarily close proximity of both microphones to the boundary hedge, or, in the case of position "**A**", hedges. There was no need for such proximity. The microphone at position "**B**" was removed on the technician's first service visit to the site. As it received noise from one hedge and not two it may have recorded a lower noise level that the microphone at position "**A**".

5.7.4 I will not repeat here any further details from Mr Tutty's submission, which I understand he has already supplied to DECC along with supporting photographs.

[11] The term "landowner" herein refers to the landowner or landowners that would benefit financially from the application.

Figure 14 Glebe Farm. ***A*** marks the position of one microphone and ***B*** the position of the second microphone. ***O*** marks the position claimed by the applicant and the yellow spot marks the grid reference provided by the applicant.

5.7.5 I note that the GPS location given in the applicant's noise information sheet for this receptor corresponds to none of the three microphone positions described above but to SW boundary of Glebe Farm, on the bank of the Skerth Drain, as indicated by the yellow dot in figure 14.

5.7.6 There are many positions in the amenity areas of Glebe Farm where a microphone could have been placed more than 10 m from hedges, trees and JCBs. In the light of all the above I can have little confidence in the validity of the Glebe Farm BNS.

5.8 Background Noise Survey at Mill Green Farm PROXY

5.8.1 Of all the receptors Mill Green Farm is the second closest to a wind turbine; it is also the receptor with the lowest measured background noise levels, and therefore one of the most vulnerable.

5.8.2 The applicant states that the resident was "hostile"; the resident acknowledges and now regrets his refusal to host a BNS. His refusal does not of course reduce his right to the protection offered by ETSU and the IOAGPG.

5.8.3 I note that the applicant gives a microphone grid reference somewhere in Glebe Farm, which would certainly not be acceptable for use as a proxy for Mill Green Farm at 2 km distance from it. I presume this is an error; there is then no precise data available on the Mill Green Farm microphone position. There is however an indication of its position on the applicant's locations map, ANIA1 Appendix 10.B; this places it on the landowner's fields.

5.8.4 Mill Green Farm is 1.5 km from two minor roads which carry almost zero traffic and 3 km from the busy A17, so road traffic noise will be minimal. There appear to be no other significant noise sources anywhere near it. The daytime background noise level might therefore be expected to be low; it is not (see ANIA1 figure E21).

5.8.5 In tranquil rural environments at low wind speeds it is usual to see evidence of the SLM "noise floor" at around 16 - 18 dB LA90, as is the case in my figure 1 above for example. The noise floor can indeed be seen in the Mill Green Farm ETSU night time chart (ANIA1 figure E22), but not on the ETSU quiet daytime chart.

5.8.6 Could it be that Mill Green Farm is producing high noise levels during the day? It may be. We cannot know, because we are relying on a proxy measurement from 1.1 km away. All we know for certain is what the noise level is at the proxy position, and that it is relatively high during ETSU quiet daytime. The proxy position is about 1.3 km from Six Hundreds Farm, compared with 1.1 km from Mill Green Farm. We do not know if the noise is from one or the other, or possibly some from each of them. Or could it all be not from the farms at all, but from the pumping station ("Ppg Sta" on figure 21, my location map) at the junction of the Skerth Drain and Holland Dike just 200 m from the proxy position?

5.8.7 The word "proxy" is absent from ETSU, but does feature in the IOAGPG, at §2.2.5:

*"When choosing a location that will serve as a proxy for others, the basis for selection is that it can reasonably be claimed, **from inspection and observation, to be representative of the non-surveyed locations**, in line with the criteria of Section 2.5. Measurement locations outside a property's curtilage (such as an **adjacent** field) may be used when access to a representative property cannot be obtained, provided that such a location can be justified as being representative."*

A location 1.1 km away cannot be described as "adjacent", and a windswept fen where the wind has a fetch of many kilometres in all directions cannot be described as representative of a sheltered garden within the amenity of a farm; the chosen proxy position is therefore not compliant with the above requirement.

5.8.8 If a microphone was positioned in an adjacent field it would only be representative if it benefitted from a similar degree of shelter from the prevailing wind as does the amenity area around the farmhouse. This could be achieved simply by ensuring the microphone was downwind of the farmhouse in the prevailing wind. The present owner of Mill Green Farm, Mr D Caswell, has intimated that he would be willing to host a BNS.

5.9 Conclusion on Background Noise Surveys

5.9.1 None of the six background noise surveys is fully compliant with ETSU or with the IOAGPG; those at 2 Council Houses, Glebe Farm, Mill Green Farm proxy and Side Bar Lane proxy – four out of six surveys - are seriously flawed.

5.9.2 It is unlikely that the receptors around any 22 turbine wind farm could all be adequately assessed with appropriate proxy background noise data using only six background noise surveys; in the present case they have certainly not been.

5.9.3 The impression I gained from my site visit to Heckington Fen was that it is a very quiet rural location except for properties close to the A17; this does not fit comfortably with the background noise levels reported by the applicant, nor would I expect it to, having probed those levels in some detail.

Table 1: All receptors assessed by applicant and additional proxies A and B.

1	1 - 4 New Cottage	Side Bar Lane proxy	
2	**2 Council House**	**2 Council House**	
3	Catlins Farm	College Farm	
4	**College Farm**	**College Farm**	
5	Derwent Cottage	Side Bar Lane proxy	
6	Elm Grange Farm	2 Council House	
7	First Cottage	Side Bar Lane	
8	Five Willow Wath Farm	Glebe Farm	
9	**Glebe Farm**	**Glebe Farm**	
10	Home Farm	2 Council House	
11	Mill Green Farm	Proxy	
12	Rakes Farm	2 Council House	
13	Rectory Farm House	2 Council House	
14	Six Hundreds Drove**	2 Council House	
15	Spinney Farm	The Old Church	
16	Swineshead House	2 Council House	
17	The Chapel House	Side Bar Lane	
18	**The Old Church**	**The Old Church**	
19	Unnamed Property (B1395)	Side Bar Lane*	
A	**Mill Green Farm proxy**		
B	**Side Bar Lane proxy**		

*Incorrectly stated as 2 Council House in ANIA1, Appendix E, Background noise and limits.

** This is the name of the road, not the residence, but it clearly refers to the property at the junction of the A17 and that road

Receptors where background noise was surveyed are in **bold type**. A and B mark the two background noise surveys that were undertaken on the landowner's fields for use as proxies.

6 Immission Noise Prediction

6.1 Introduction

The prediction of the immission noise at each assessed receptor requires knowledge of:

(a) the distances between each receptor and all the turbines,

(b) the turbine noise power, and the uncertainty thereof, at 10 m reference height wind speeds from 4 to 12 m/s, and

(c) the summed attenuation of the noise, and the uncertainty thereof, between all turbines and each receptor.

6.1.1 For (a), an uncertainty of the order of a metre arises from the use of Ordnance Survey grid coordinates to define turbine and receptor positions. This translates to a change in immission noise of less than 0.1 dB at a receptor 1 km from the wind farm, which is negligible compared with the uncertainties in (b) and (c) and can therefore be ignored. It is however necessary to correctly define the amenity areas of all receptors and to predict the immission noise level at its nearest point to the wind farm. Account should also be taken of any requested micrositing limits for the turbines, either in the setback calculations or by a planning condition which forbids movement towards close receptors.

6.1.2 The ISO 9613-2 International Standard[13] has long been used for the prediction of wind turbine immission noise levels, and its use is now endorsed by the IOAGPG which in its turn is endorsed by DECC. I have calculated immission noise predictions using the applicant’s turbine noise data in full compliance with the IOAGPG guidance and ISO 9613-2. For this purpose I use in–house software which is available for audit and test by decision-makers. A screen shot of the user interface is shown in figure 20.

6.1.3 I agree with the arithmetic of the applicant’s noise immission prediction calculations; indeed when I use the same input data as the applicant I arrive at exactly the same answers as does the applicant for the immission noise levels at Mill Green Farm and Home Farm, the two most impacted receptors. I have no reason to believe that this would not be the case for all receptors. I do however have a concern with its methodology; the applicant ignores the prediction uncertainty, an important and integral part of the ISO 9613-2 standard.

6.2 Receptor Setback Distances

6.2.1 The most noise impacted receptor is Home Farm, to the south west of the proposed turbines. The applicant has defined the closest point of its amenity area as 998 m from the nearest turbine (T6). The correct distance is 885 m. Home Farm borders the A17 to its south, so the residents value their amenity area towards the north to escape the traffic noise from the A17. They have written to DECC.

6.2.2 Home Farm residents first agreed to host noise monitoring equipment, but when they understood from the Hoare Lea technician that to do so would enhance the probability of the application gaining consent they declined to host it. In ANIA1 Home Farm, with its amenity area 250 m from the A17, uses the background noise curve from 2 Council Houses, with its amenity area at 55 m from the A17 and its far from compliant microphone position, as a proxy. This has no validity whatever.

Table 2: Representative receptors assessed within the 35 dB(A) noise contour

Receptor number and name	Eastings	Northings	My minimum setback m	From turbine number	HL minimum setback m	My emission noise dB(A)
1 Five Willow Wath Farm	518595	346815	1074	1	1100	40.7
2 Glebe Farm	518527	346200	1059	1	1115	41.8
3 The Chapel House	518471	345472	1142	1	1221	41.3
4 Cncl houses Sidebar L	518620	345153	1096	3	1090	41.6
5 Bungalow 2 Sidebar L	518644	344940	1187	3		41.1
6 Elm Grange	519046	344579	1127	6	1167	42.0
7 Home Farm	519357	344580	885	6	998	43.7
8 Beech House	519460	344342	1009	6		42.7
9 Rectory Farm	519666	344208	1046	6	1048	42.6
10 2 Council Houses	520189	343974	1111	15	1101	42.3
11 Ashleigh House	520365	343952	1081	15		42.4
12 6 Hundreds Drove	520602	343714	1222	20	1230	42.4
13 Rakes Farm	520835	343803	1098	20	1124	41.3
14 Swinehead House	521126	343577	1341	20	1340	39.5
15 Houses, Brown's Drove	521754	343446	1684	20		37.5
16 Caton House	521800	344336	1060	20		41.7
17 College Farm	521878	344472	1065	20	1100	42.0
18 Spinney Farm	522917	346006	1504	21	1407	38.5
19 Sutterton Drove	523053	346940	1956	21		36.5
20 Houses, Claydike Bank	522085	346998	1260	16		40.8
21 The Old Church	521875	347297	1273	16	1241	40.4
22 2 Houses Claydike Bk	521790	347334	1242	16		40.5
23 Mill Green Farm	519911	347321	1010	1	1023	43.2
24 Bungalow W Sidebar	518468	345473	1145	3		41.2
25 White House Farm	517870	345870	1725	2		37.9
26 Chestnut House Farm	520705	348833	2312	11		35.4
27 Pattingden House	518536	348346	2231	1		35.0
28 Ashtree Farm	523680	346438	2332	21		34.8
29 Sellars Farm	522415	347675	1925	16		36.9

6.3 Turbine Noise Data Sourcing

6.3.1 ANIA1 neither appends nor references the Enercon document from which the applicant claims to have used the turbine noise power data. I have used the noise data from the Enercon specification[14] appended hereto. It will be seen there that the noise power data is explicitly not warranted (page 1):

“Updates: ENERCON GmbH reserves the right to continuously update and modify this document and the items described therein at any time without prior notice.”

and in §7 on page 3 that:

“The sound power level of a wind turbine depends on several factors such as but not limited to regular maintenance and day-to-day operation in compliance with the manufacturer’s operating instructions. Therefore, ***this data sheet can not, and is not intended to, constitute an express or implied warranty towards the customer that the E-82 E2 WEC will meet the exact sound power level values as shown in this document at any project specific site****.”*

The IOAGPG – and long standing good practice before it - therefore requires that, given the unwarranted nature of the data and the absence of declared uncertainties an uncertainty margin of 2 dB be added to it.

6.3.2 The applicant has indeed added that margin for wind speeds up to 7 m/s, but has added only 1.5 dB for wind speeds over 7 m/s. This is wrong; irrespective of any of the other flaws in ANIA1, correcting this one takes the immission noise level at Mill Green Farm above the ETSU limit.

6.3.3 I have heard it argued – unsuccessfully – that §5 of the Enercon document (which uses a standard Enercon template) is a warranty. It is not; when read carefully it is clearly a statement of the combined uncertainty of the typical Class1 instruments that would be used to measure the turbine noise in any subsequent contractual compliance testing:

*“…****if*** *the sound power level* ***is*** *measured…****If*** *the difference between total noise and background noise…”*

6.3.4 The turbine spectral data sourced by the applicant is satisfactory; I have used the same data source and therefore the same data as the applicant in my calculations.

6.4 ISO 9613-2 Prediction Uncertainty

6.4.1 ANIA1 is not compliant with the IOAGPG’s advice on the use of International Standard ISO 9613-2 for attenuation prediction. The Standard includes a statement of the *“estimated accuracy”* of the predictions in its table 5, reproduced immediately below.

Table 5 — Estimated accuracy for broadband noise of L_{AT}(DW) calculated using equations (1) to (10)

Height, h *)	Distance, d *)	
	$0 < d < 100$ m	100 m $< d < 1\,000$ m
$0 < h < 5$ m	± 3 dB	± 3 dB
5 m $< h < 30$ m	± 1 dB	± 3 dB

*) h is the mean height of the source and receiver.
d is the distance between the source and receiver.

NOTE — These estimates have been made from situations where there are no effects due to reflection or attenuation due to screening.

6.4.2 Prior to publication of the IOAGPG table 5 of the standard was often ignored in wind farm NIAs, which clearly did not comply with good practice then, and which now complies neither with good practice nor with the DECC endorsed planning guidance of the IOAGPG. If a well reputed International Standard is used for the prediction of wind turbine noise it must be used in its entirety, not “cherry picked”.

6.4.3 The IOAGPG does propose two caveats in §4.1.4:

"…the use of "soft-ground" factor should be avoided, and the full theoretical effects of terrain screening will usually not be achieved."

Both of which are due to the unusual height of wind turbines, and which, if ignored, would allow under-prediction of immission noise. Thus there are caveats – but nowhere in the IOAGPG however is there one proposing that the uncertainties stated in table 5 of ISO 9613-2 should be ignored.

6.4.4 I cite below two planning appeals decisions which support my use of table 5; both are from appeals where I represented local residents in the matter of noise, and criticised the applicants' selective use of ISO 9613-2 whilst ignoring the ± 3 dB uncertainty stated in its table 5.

6.4.5 Land associated with Westwood Farm, appeal ref APP/R1038/A/14/2228756 [15].

Inspector P J Asquith:

"From all I have seen, read and heard I consider the main issues in this case to be:

- *the impact of the proposal on the appearance and character of the area; and*
- *the proposal's impact on the living conditions of nearby residential occupiers **with particular reference to operational turbine noise**.*

*My views on the **uncertainty** in relation to the possibility of impact on living conditions of nearby residents **as a result of operational turbine noise** add weight to this conclusion."*

6.4.6 Land adjacent to Louth Canal, appeal ref. APP/D2510/A/13/2200887 [16].

Inspector Zoë Hill. The reasons for dismissal began:

*"The proposed development would have an adverse impact on the residential amenities of Eastfield Farm due to **overbearing outlook and noise**…* (§23)

And more specifically:

Whether or not … the approach to uncertainty in the modelling increase the level of noise predicted, which MWAG calculates that it does at critical wind speeds, albeit marginally, this cannot be seen as the best practice …(§441)

*Nor can the **lack of adherence to ISO 9613-2 in terms of uncertainty** for noise predictions be seen as best practice. (§442)*

The developer's appointed acoustic consultant for this application, and the author of its NIA, was Hoare Lea.

6.5 Conclusion on Immission Noise Levels

6.5.1 It is fairly clear and unsurprising that many receptors will show exceedances, as some of the applicant's original "headroom" margins were close to zero, and I have accounted for the ± 3 dB uncertainty required by table 5 of ISO 9613-2 and the applicant's turbine noise power understatement and overstated setback distances.

6.5.2 As already stated, the above predictions take no account of the flawed background noise surveys, nor of the emerging amplitude modulation problems now known to be affecting many UK wind farms, particularly those with stubby towers.

7 Exceedances

7.1 Introduction

7.1.1 As ETSU noise limits are relative rather than absolute both the background noise and the predicted turbine immission noise at each receptor must be known in order to determine compliance with those limits. As the applicant's background noise surveys are not compliant the required comparison cannot be made, but in the absence of reliable background noise data it is still meaningful to compare immission noise predictions.

7.1.2 ANIA1 predicts very little headroom at the most impacted receptors and suffers from several non-compliances. It is therefore to be expected that there will be considerable exceedances at many receptors when those non-compliances are resolved.

7.1.3 Some problems with the proposed wind farm design will certainly cause increased turbine emission noise levels, but it is not possible to quantify the increase more accurately than "several dB". These are covered in §7.2. Where it is possible to quantify the contributions to exceedances from each non-compliance this is done in §7.3. The setting of the ETSU lower daytime limit is discuss in §7.4

7.2 Influence of wind farm design on immission noise levels

7.2.1 There are three factors associated with the proposed wind farm which will significantly affect its noise emissions, but to an extent that is difficult to quantify. The first is the "stubby tower" design; this is a major concern for the variation application, but is also relevant for the original design, as it will be seen in the appended turbine noise specification that Enercon offer the E82-2.3MW turbine with a range of five very different hub heights. These are illustrated to scale in figure 15. Thus the original application had already proposed the shortest tower available, at 78 m hub height, which has the highest probability of stall at blade zenith with the increased aerodynamic and very low frequency noise that this implies. Figure 16 shows the considerable difference between the original E82 turbine and the General Electric GEs 103 turbine proposed for the variation.

138 m 108 m 98 m 85 m 78 m

Figure 15: The five hub height options for the Enercon E82 turbine shown to scale.

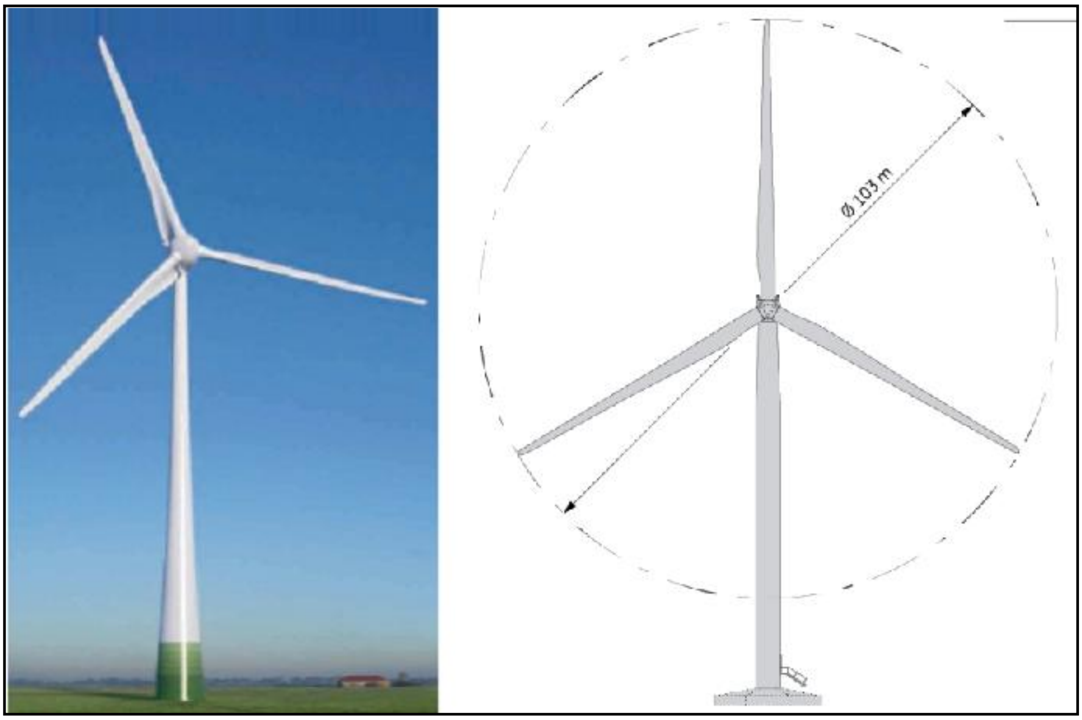

Figure 16: Enercon E82 turbine proposed in original application compared with GEs 103 turbine proposed in variation application; both are shown to the same scale.

7.2.2 The second factor is inflow turbulence, which will increase noise emissions from all turbines except those in the first row facing into the wind. As government recommended packing density (i.e. the number of turbines per square km) is exceeded by a factor of 1.2 in the original design and by a factor 1.9 in the present variation application it is unlikely that the turbine manufacturer's warranty would be valid as maximum permitted inflow turbulence is usually specified in any wind turbine warranty. This is because inflow turbulence affects not only noise levels but also mechanical reliability, via fatigue, bearing life, etc.

7.2.3 The third unquantifiable factor is the extent to which the flawed background noise surveys have allowed excessive turbine noise levels to appear ETSU compliant. The combination of non-compliant microphone positions and inappropriate use of proxies may well have added as much as 10 dB or so to the true background noise at some receptors. Some of the addition will have been without effect where the derived noise curve is determined by the ETSU lower daytime limit, which itself enters into the equation as the applicant has set it at 40 rather than 35 dB LA90.

7.3 Quantifiable non-compliances

7.3.1 These too are three in number, of which two relate to uncertainty and one to setback distance calculation. At any given wind speed an error in the turbine emission noise power translates dB for dB to the same change in headroom at any receptor. The same applies to errors in background noise measurement.

7.3.2 In the present case adherence to the ± 3 dB uncertainty in attenuation prediction specified in ISO 9613-2 simply subtracts 3 dB from the headroom at all receptors.

7.3.3 Using the correct turbine noise data uncertainty as specified in the IOAGPG subtracts 0.5 dB from the headroom at all wind speeds above 7 m/s.

7.3.4 The setback distance error calculation is more complex. The applicant's largest receptor position error happens to be Home Farm, which also happens to be the nearest and the most noise-impacted of all the receptors. The applicant's error in the OS grid reference for this receptor causes a 0.93 dB understatement of the immission noise at Home Farm. This is much less significant than the inappropriate use of the 2 Council Houses BNS as a proxy, but is nevertheless still significant.

7.4 The ETSU lower daytime limit

7.4.1 In ANIA1 §10.28 the applicant discusses the setting of the ETSU lower daytime limit to a value between 35 dB LA90 and 40 dB LA90. The applicant's acoustician has been relieved of this responsibility, which has been passed to the decision maker, in the present case the relevant Secretary of State.

7.4.2 I will nevertheless comment on the applicant's argument. The applicant states (§10.28):

"The precise choice of criterion curve level within the range 35 dB(A) to 40 dB(A) depends on a number of factors: the number of noise affected properties, the likely duration and level of exposure and the potential impact on the power output of the wind farm."

This is a difficult balancing task: the weighing of the perceived benefit to the planet against the demonstrable harm to local residents. The applicant states in §10.73:

"Given the scale of this scheme, coupled with the effect that having a limit at the lower end of this range would have on the number of turbines installed, it is considered wholly appropriate to set the limit toward the upper end of the range."

In fact the applicant has set the limit at the upper range, not toward its upper end.

7.4.3 The applicant continues:

"For example at the time the guide [ETSU] was produced, a wind farm site comprising around 85 turbines would have been required to achieve a similar generating capacity to that which is proposed at Heckington Fen with 22 turbines"

When ETSU was published in 1997 1.6 MW turbines were commercially available; to achieve the applicant's 50 MW target at that time 32 such turbines would have been required, not 85. But more importantly, the noise emission power of a wind turbine is, unsurprisingly, proportional to its electrical generating power. As evidence thereof figure 17 [Sondegaard, 17] charts a large number of accredited independent turbine noise output power versus electrical output power measurements which demonstrate this rather obvious truth. My superimposed red line shows exact dB for dB proportionality; it will be seen that Sondergaard's two regression lines are very nearly parallel to it.

7.4.4 In §10.76 the applicant offers the opinion that:

"...the maximum absolute limit of 40 dB(A) represents a very stringent criterion that places considerable burdens and constraints on the expansion of renewable energy from wind farms."

This extraordinary statement is very much at variance with the intention of the authors of ETSU, as expressed in its opening paragraph (§1 page iii), to give:

"…indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind

farm developers or local authorities. The suggested noise limits and their reasonableness have been evaluated with regard to regulating the development of wind energy in the public interest.”

Inasmuch as stringent means precise I would agree that the figure 40 dB(A) is indeed as stringent as it can be at 40 ± 0 dB, but if applicant believes it too onerous for the developer then neither I nor ETSU agree with the applicant.

7.4.5 If the Secretary of State is minded to consider any increase above the 35 dB LA90 ETSU lower limit the harm that has to be weighed against the perceived benefit of the proposal is proportional to the number of wind farm neighbours that would be affected by turbine noise. This can reasonably be equated at least to all the receptors that would need assessment using the standard ETSU procedure; indeed the IOAGPG states in §2.2.1:

“The ‘study area’ for background noise surveys (and noise assessment) should, as a minimum, be the area within which noise levels from the proposed, consented and existing wind turbine(s) may exceed 35 dB LA90 at up to 10 m/s wind speed.”

7.4.6 Any ETSU assessment starts with the establishment of the 35 dB LA90 noise contour. When calculated in compliance with ISO 9613-2 this contour is fairly well approximated by a circle of 3.2 km radius, as shown in red on my location map (figure 21). Fortunately the flawed background noise surveys of ANIA1 do not influence the 35 dB LA90 contour, which is dependent only on the noise power emitted by the turbines. It can be seen from the location map that, in spite of the applicant’s claim in ANIA1 §10.40 that *“The proposed wind farm is located in an area of relatively low population density”,* there are within the red circle over 100 homes therefore several hundred residents, more of which should have had background noise surveys and all of which should have been considered.

7.4.7 There is an element of self-fulfilment in the applicants approach to setting the ETSU lower daytime limit at 40 dB. Only a relatively small number of receptors not much further than a kilometre from a turbine were assessed. Due to the three main flaws in ANIA1 (overstatement of background noise, understatement of turbine

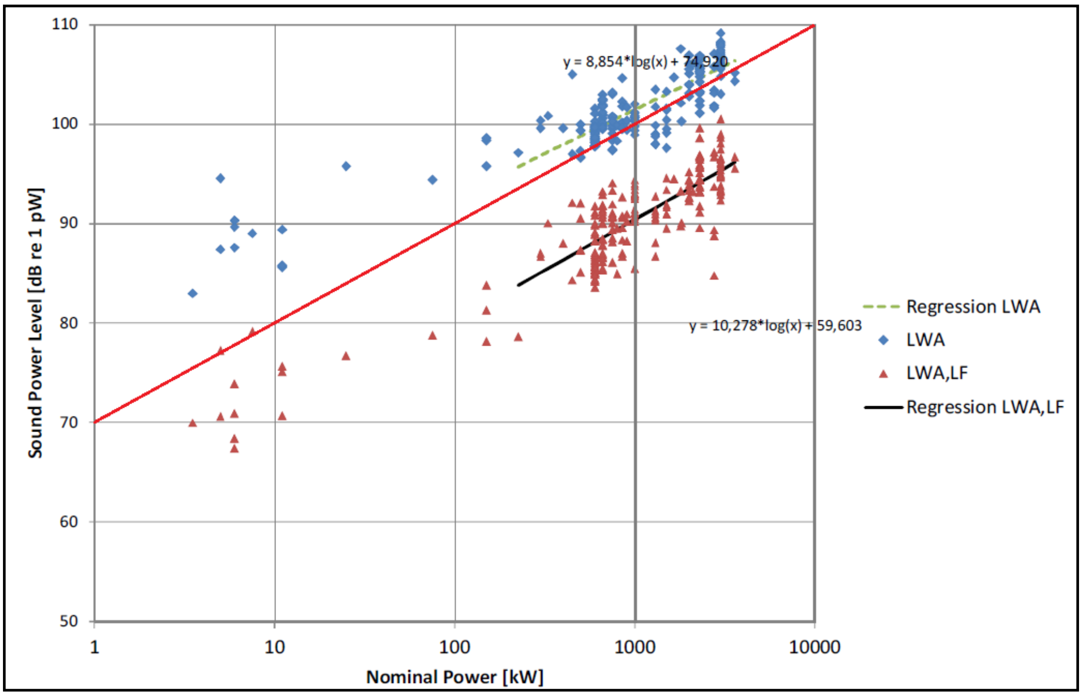

Figure 17: The linear relationship between electrical power and noise power [Sondegaard]

noise and disregard of uncertainties) all the receptors were deemed compliant, and only a few receptors were weighed against 50 MW of renewable energy power in the acoustician's planning balance which may at that time have been felt to justify the 40 dB LA90 daytime lower limit. If all of these flaws are corrected the study area greatly increases, which weighs heavily against the applicant's proposed 40 dB LA90. This is however somewhat academic as the setting of the lower limit is no longer in the gift of the applicant's acoustician.

8 Overall Conclusion

8.1.1 In any NIA using the ETSU standard procedure there are six steps:

(a) Background noise data acquisition
(b) Derivation of ETSU immission noise limit curves from (a)
(c) Sourcing of turbine noise power data and uncertainty thereof
(d) Determination of all turbine to receptor distances
(e) Calculation of noise attenuation between all turbines and receptors
(f) Demonstration that ETSU limits are not breached

8.1.2 The background noise surveys were flawed for a variety of reasons

8.1.3 ETSU immission noise limit curves were correctly derived but non-compliant as based on non-compliant data acquisition.

8.1.4 I have a significant issue with the sourcing of the turbine noise data.

8.1.5 I have significant issues with some immission prediction point positions (which differ of course from the microphone positions)

8.1.6 I have a serious concern with the selective use of ISO 9613-2, ignoring its stated uncertainty.

8.1.7 Given that the wind farm design had, by the applicant's own calculations, little or no "headroom" at any surveyed receptors the inevitable consequence of rectifying the errors I have found inevitably demonstrates that the applicant's wind farm design is not compliant with ETSU or the IOAGPG.

8.1.8 The applicant, by proposing a wind farm with an installed power greater than 50 MW, was able to circumvent local opposition by removing the decision from local to central government, at a time when the relevant government department, DECC, had great enthusiasm for wind farms but little understanding of their potential impacts on wind farm neighbours. Having been assured by the developer on the one hand that there would be no adverse impacts from the proposal and on the other hand that objection was futile as the decision was a predetermined formality, in particular Heckington Parish Council, South Kyme Parish Council and Amber Hill Parish Council felt that their concerns would carry little weight in the decision making process. Local residents likewise also registered their concerns.

8.1.9 More recently when affected residents and local Parish Council's discovered the true implications – and indeed the existence - of the variation application they did object, in large numbers and from a position of knowledge. The chosen site is simply too small for a 50 MW, let alone 66 MW, wind farm. **It is now apparent that the original consent was gained in spite of a defective noise impact assessment; if constructed the wind farm would have produced noise well in excess of government limits. If the variation application were to be consented the noise excess would be even greater.**

9 Comments on ANIA2

9.1 Introduction

9.1.1 For the avoidance of repetition I will not comment on any paragraphs in ANIA2 that simply recall content from NIA1.

9.1.2 In ANIA2 §9.2 Hoare Lea, the firm responsible for both ANIA1 and ANIA2, reports its involvement in:

(a) the IOA noise working group (IOANWG) which produced the Good Practice Guide to ETSU, the IOAGPG [7],
(b) the IOA Amplitude Modulation sub-group (IOA AMWG)
(c) the RenewableUK AM research project that led to the publication of reference [19].

This claim seems too modest, as the firm was also deeply involved in the authorship of ETSU, and appeared to me to be very much leading, not just involved in, the IOAGPG team and the AMWG team.

9.1.3 There appears to me to be a conflict of interests when standards and guidance intended to protect wind farm neighbours against unacceptable noise levels are authored by those who then use them to assist wind energy developers seeking planning consents.

9.1.4 It is also quite extraordinary that in the present case the authors have failed to comply with what is largely their own guidance.

9.1.5 The third bullet in ANIA2 §9.4 refers to *"amending[12] the turbine rotor diameter"* from 90 m to 103 m. I have commented elsewhere on this, but I note here that the original candidate turbine was the Enercon E82. Whilst a 13 m increase (from 90 to 103 m) in rotor diameter is less than a 21 m increase (from 82 to 103 m) neither can reasonably be described as "minor". Any repeat variation application must be compared not with the latest consented state of a project but with its original consented state, otherwise the rotor diameter could be increased *ad infinitum* with repeated variation applications one metre at a time, as each one of a series of 1 m increases may well be considered minor.

9.1.6 Without reliable background noise information for the project it is not possible to calculate the extent to which the ANIA1 understates the exceedances of ETSU noise limits; it is clear however that there will be unacceptable exceedances at several receptors. As ANIA2 predicts immission noise levels similar to those in ANIA1 using the same flawed background noise data the variation project would be as far from compliant as would be the original project. In reality the variation project would be considerably worse for local residents because of the susceptibility of the proposed stubby tower turbines to high levels of EAM.

[12] OED: *"making minor changes to"*.

10 More on Amplitude Modulation

10.1 Introduction - Two Decades of Without Progress

10.1.1 Amplitude modulation of wind turbine noise was described in 1996 on page 12 of ETSU. The description was followed by the following statement:

> *Current research projects aimed at more fully characterising the aerodynamic noise emissions from wind turbines are described in Chapter 9 on Further Work. These projects include measurements of blade swish and **low frequency noise** and vibration emissions.*

A timetable for reviewing the *"further work"* was even proposed on page 2 of ETSU:

> ***The Noise Working Group therefore suggests this report and its recommendations are reviewed in two years' time.***

10.1.2 Not two years later, but two decades later, guidance based on competent and objective research into so-called amplitude modulation is still wanting. The IOA AMWG (Amplitude Modulation Working Group), the majority of the members of which work either in or predominantly for the wind energy industry, have produced a "discussion document" [18] which relies heavily on the RenewableUK Research Report to which the applicant refers [19], which essentially continues to deny the existence of significant levels of low frequency sound and infrasound.

10.1.3 A group of interested parties, including wind farm acousticians, physicists, engineers, legal consultants, and also victims of wind farm noise, have therefore formed the Independent Noise Working Group (INWG), and have produced a series of papers available at [20]. I draw attention to my own paper there, WP1, commissioned by the INWG. Although members of the INWG have been selected to ensure independence of the wind industry the team does of course include members of the IOA and other relevant professional scientific and academic institutions.

10.1.4 Essentially the wind industry has persisted in claiming that levels of infrasound and low frequency sound from wind turbines are negligible, and that complainants are victims of a "nocebo effect", whereby an alleged general dislike of wind turbines somehow undergoes a "psychosomatic" transformation to the oft reported symptoms of nausea, headaches, motion sickness, sleep disturbance etc. as exemplified by this slide from a presentation by wind industry acoustician Leventhall:

> ***Conclusions***
>
> 1. *Infrasound from wind turbines is not a health problem.*
> 2. *Effects of wind turbine noise on health are mediated through annoyance from audible noise, particularly if aerodynamic fluctuations occur (swish).*
> 3. *Attitude to a noise source is a large factor in annoyance from the source.*
> 4. *The Wind Turbine Syndrome is the result of stress from annoyance by audible noise from wind turbines, similar to annoyance from any other noise source.*

The nocebo effect is an entirely reasonable notion. Just as a medically inert placebo can improve the perceived health of a patient if he or she believes that it will, the "nocebo effect" can appear to worsen the health of a patient if he or she believes that it will. The word nocebo rarely arises in the normal medical vocabulary, and has no research to support it - for obvious ethical reasons.

10.1.5 The wind industry, in spite of its abundant resources, has not made, or at least has not published, any measured data to support Leventhall's assertions. Unusually however there is a test report, commissioned by a turbine manufacturer from an accredited independent test house, Windtest Grevenbroich gmbh, which is in the public domain, and which does include infrasound measurements; see figure 18.

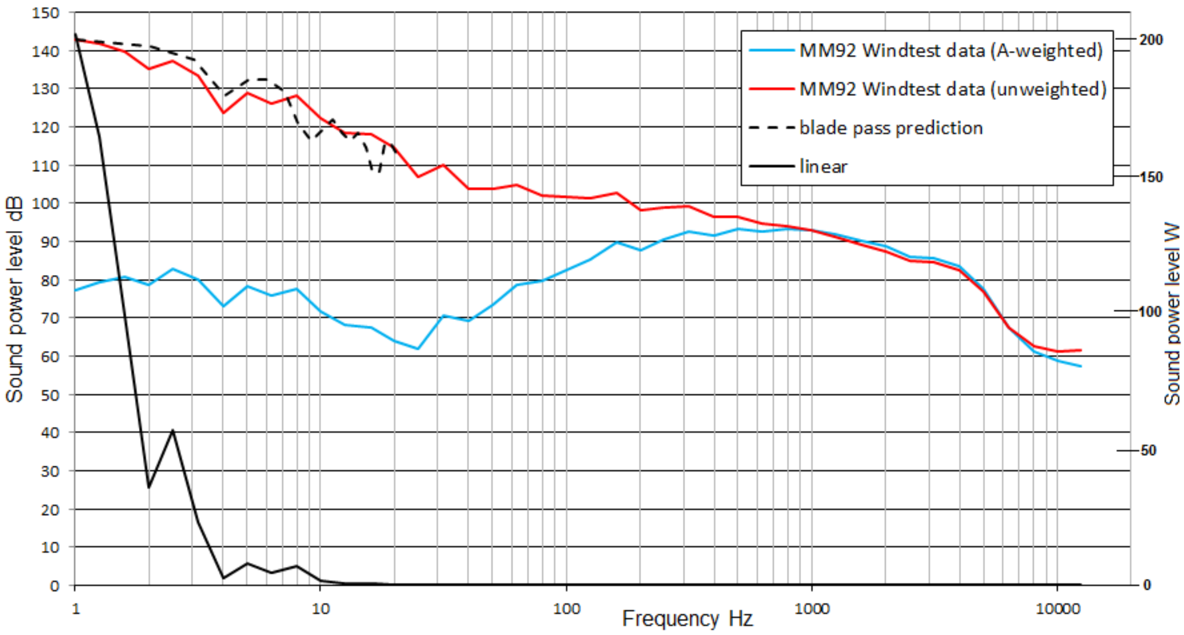

Figure 18 Measured noise emission power for RePower MM92 wind turbine,1 Hz to 10 kHz, A-weighted (blue) and unweighted, the latter both logarithmic (red) and linear (black).

10.1.6 Sound is just a relatively small periodic (or aperiodic in the case of noise) variation in air pressure. The human ear is a miracle of evolution. Human hearing is remarkable for its 140 dB range of intensity between the threshold of detection and the threshold of pain. That may not impress, until expressed as a simple ratio rather than logarithmically in decibels. The ratio is 10^{14}, or 100,000,000,000,000.

10.1.7 The 140 dB is achieved by "compression". The otoliths (three very small bones) and associated muscles between the eardrum and the inner ear act as an almost instant automatic volume control; quiet sounds are amplified and loud sounds are attenuated. Very loud sounds cause the stapedius muscle to substantially isolate the inner ear.

10.1.8 The inner ear is not only responsible for hearing however; it is also responsible for the vestibular function: balance. This function is sensitive to gravity, via the semi-circular canals of the inner ear. When relatively high levels of infrasound affect the semi-circular canals it is interpreted as motion, with gravity varying in force and direction. When the inner detects motion but the eye does not the conflict leads to motion sickness – or "wind turbine syndrome".

Yet the wind industry persist with denials:

"If you cannot hear a sound … it does not affect you." [21]

"Infrasound … is below the audible threshold and of no consequence" [22]

The notion that "what you cannot hear cannot harm you" does not work for any other senses. We know that infra-red radiation burns, that ultra-violet can damage the eye and cause skin cancer. Many poisons are tasteless, many poisonous gases are odourless. Returning to the case of sound, ultrasound can crack kidney stones. Ultrasound in this case is of course a benefit, but only because it is correctly targeted. The UK HPA UK published a report by the independent Advisory Group on Non-ionising Radiation (AGNIR) in 2010 which recommended limiting exposure of the general public to airborne ultrasound to a SPL of 70 dB at 20 kHz[23]. There is no limit yet for exposure to infrasound.

10.2 Excessive Amplitude Modulation – when Swish Turns to Thump

10.2.1 Amplitude modulation is considered excessive when the “modulation depth” of the time series envelope exceeds the 2 – 3 dB(A) range reported in ETSU; compared with AM the peaks of EAM are narrower, with modulation depths up to 30 dB reported. The trough amplitudes show no change at the onset of AM. The waveform thus changes radically, but over a relatively small part of the blade pass period. An example of a high (25 dB(A)) modulation depth time series chart from Huson [24] is shown in figure 19.

10.2.2 Much of the increase in modulation “depth” appears to be due not to modulation of aerodynamic noise frequencies but to tones at turbine blade pass and rotation frequencies, particularly when these excite blade and tower resonances, and to harmonics of all these.

10.2.3 True AM as defined in other engineering disciplines would have the troughs descending as much as the peaks ascending; in the present case, where the troughs do not descend, it is more logical to refer to modulation height than modulation depth, as I do in all that follows.

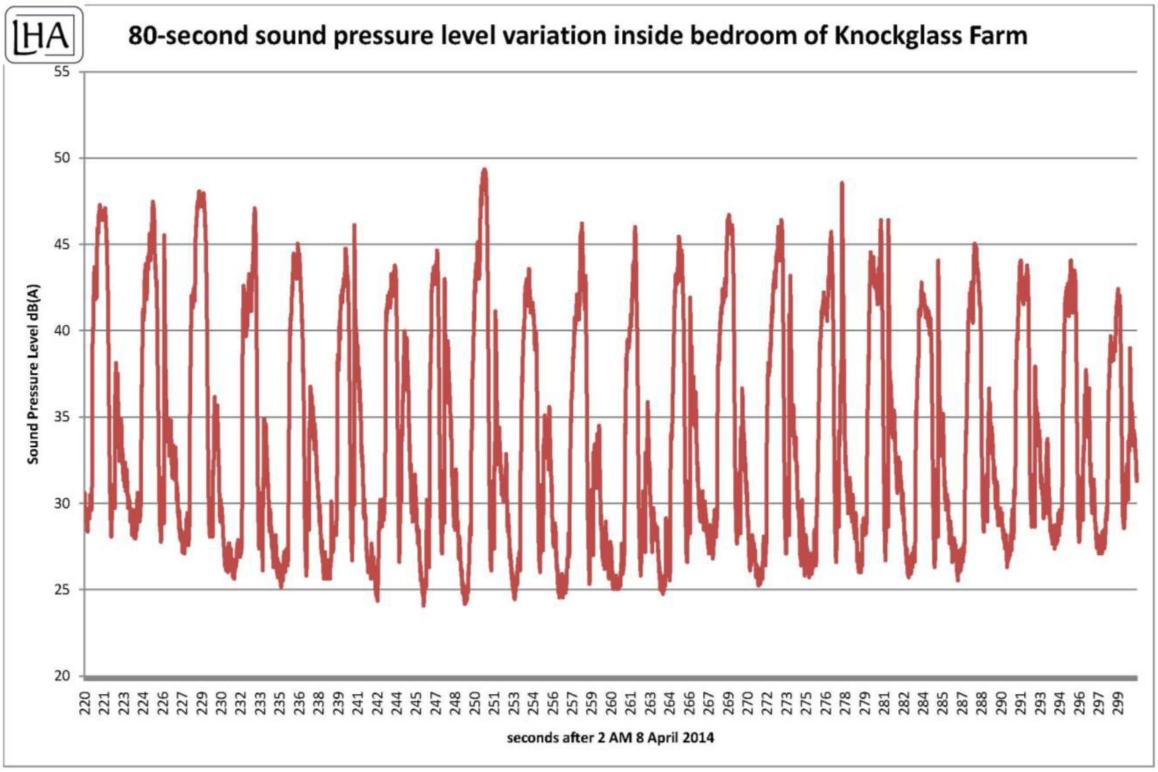

Figure 19: High levels of EAM (25 dB(A)) at Knockglass Farm. Credit: Huson [24].

10.2.4 The use of the term “modulation” in the acronyms OAM and EAM was unfortunate as it pre-judged the spectral content of EAM at a time when it was less well understood. In signal processing terms a modulated waveform is typically the product of a carrier frequency multiplied by a normally much lower modulation frequency or band of frequencies. EAM however is the sum of incoherent noise, modulated both in frequency and in amplitude, together with high levels of very low frequency tones. "Modulation" should therefore be understood by a lay definition rather than any technical definition. The use of the term does not of course suppress the very low frequencies from wind turbine noise, but it does appear to have suppressed any serious consideration thereof by the wind industry or its acousticians.

10.2.5 The RenewableUK AM research report [19] ("the RUK report") states that EAM is entirely due to increased aerodynamic noise from the turbines blades when they stall at blade zenith ("12 o'clock") in high wind shear. I will show below that this can explain only a part of the greater observed modulation heights; a major contribution comes from noise well below 100 Hz. I will also show that the RUK report, and the IOA AMWG discussion document [18] largely derived from it, repeatedly exclude any consideration of acoustic emissions at frequencies below 100 Hz. The RUK report includes no measurements below 100 Hz to justify the exclusion however. In truth the greatest observed modulation heights are fairly easily explained by consideration of the very low frequency emissions which are a consequence of the structural dynamics of large modern wind turbines rather than aerodynamic noise from the blades. These very low frequency emissions are well known [25, 26, 27, 28, 29] to turbine manufacturers, but by reason of mechanical fatigue issues rather than noise nuisance.

10.3 The Normal Wind Turbine Noise Spectrum

10.3.1 The major part of the aurally perceived (i.e. A-weighted) acoustic emissions from turbines falls within the frequency range 100 Hz to 4 kHz, as seen in the logarithmic A-weighted trace (blue) of figure 19, which is plotted from data in the referenced independent test report [30] by Windtest gmbh for the RePower MM92. The major part of the acoustic power however falls below 4 Hz, as seen in the unweighted traces (linear, black and logarithmic, red) of figure 9; 4 Hz is well below the threshold of hearing. The A-weighted trace reflects the annoyance value of audible wind turbine noise, whereas the two unweighted traces reflect the true sound pressure of, and therefore some indication of the potential health hazards from, wind turbine acoustic emissions.

10.3.2 The reason given in ETSU for setting the night time lower fixed turbine noise limit at 43 dB LA90, as opposed to the outdoor daytime limit of 35 dB LA90, is the assumption of 8 dB sound attenuation in passage through an open window. This assumption is valid at normal audio frequencies but certainly does not apply at very low frequencies; even with windows closed there is little or no attenuation from outdoors to indoors, and sometimes amplification due to room resonances. It is therefore not surprising that the great majority of wind turbine noise complaints relate to sleep deprivation indoors, and not to annoying noise levels outdoors.

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Emission Noise Predictor

ISO 9613-2 Wind Turbine Immission Noise Predictor

New WF | Open WF | Save WF

Project name and refere

Wind turbine positions

Number of WTs: 22 | Hub height default: 74 | Fix | Micro-siting: 0 | Gm: 0.5

WT number	Eastings	Northings	Altitude	Hub height	Gnd attn	On	A/B	Mode attn
1	519572	346370	2	74	0.5	☑	A	0.0
1	519572	346370	2	74	0.5	on	A	0.0
2	519586	346048	2	74	0.5	on	A	0.0
3	519600	345643	2	74	0.5	on	A	0.0
4	519920	345963	2	74	0.5	on	A	0.0
5	519933	345564	2	74	0.5	on	A	0.0
6	519983	345205	2	74	0.5	on	A	0.0
7	520210	346312	2	74	0.5	on	A	0.0
8	520237	345901	2	74	0.5	on	A	0.0
9	520257	345556	2	74	0.5	on	A	0.0

Receptor positions

Number of receptors: 29 | Fix | Prediction height agl: 4

Rec number	Rec address	Eastings	Northings	Altitude
1	Five Willow Wath Farm	518595	346815	4
1	Five Willow Wath Farm	518595	346815	4
2	Glebe Farm	518527	346200	3
3	The Chapel House	518471	345472	3
4	Cncl houses Sidebar L	518620	345153	3
5	Bungalow 2 Sidebar L	518644	344940	3
6	Elm Grange	519046	344579	3
7	Home Farm	519357	344580	3
8	Beech House	519460	344342	3
9	Rectory Farm	519666	344208	4

Meteorological data (ISO 9613-2 table 2)

○ Off

	◉	○	○	○	○	○
Temp:	10°C	20°C	30°C	15°C	15°C	15°C
RH:	70%	70%	70%	20%	50%	80%
63 Hz	0.1	0.1	0.1	0.3	0.1	0.1
125 Hz	0.4	0.3	0.3	0.6	0.5	0.3
250 Hz	1.0	1.1	1.0	1.2	1.2	1.1
500 Hz	1.9	2.8	3.1	2.7	2.2	2.4
1 kHz	3.7	5.0	7.4	8.2	4.2	4.1
2 kHz	9.7	9.0	12.7	28.2	10.8	8.3
4 kHz	32.8	22.9	23.1	88.8	36.2	23.7
8k Hz	117.0	76.6	59.3	202.0	129.0	82.8

Attenuation (ISO 9613-2, eqns 3 to 9 (except 6) and table 3)

WTnumber: 1 | Step ☐ | Rec number: 7 | Table 5, ± dB: 3 | RSS ☐ | LAeq/LA90: 2 | Show

G source	G middle	G recvr	A div 1m	A atmos	A barrier	A misc	A atmos	A total	LfT dB(A)
-1.50	0.00	-1.50	77.56	0.21	0		0	74.77	11.93
-0.75	0.00	1.26	77.56	0.85	0		0	78.91	15.79
-0.75	0.00	0.27	77.56	2.13	0		0	79.20	15.20
-0.75	0.00	-0.75	77.56	4.04	0		0	80.10	16.90
-0.75	0.00	-0.75	77.56	7.87	0		0	83.93	14.87
-0.75	0.00	-0.75	77.56	20.63	0		0	96.69	-2.79
-0.75	0.00	-0.75	77.56	69.77	0		0	145.83	-64.23
-0.75	0.00	-0.75	77.56	248.89	0		0	324.95	-251.45

8 most rece

Wind turbine noise spectrum A

dB(A)	1/3 octaves 8 m/s at 10 m ht			octaves
63 Hz				86.7
125 Hz				94.7

Wind turbine noise spectrum B

dB(A)	1/3 octaves 8 m/s at 10 m ht			octaves
63 Hz				
125 Hz				

Immission noise vs wind speed

m/s at 10 m	SWL LAeq	1.645 σ	SWL+ ΣUc	Immission
4	90.0	2.0	95.00	29.65

Chestnut House Farm
R26
Cow Drove
Clay Bank
R27
Pattingden House
CP Bdy
Mary Land
Maryland Drain
Sutterton Drove
Vicarage Farm
South Kyme Fen
17
18
19
20
21
48
49
47
46
45
AMBER HILL CP
R22
R21
Mill Green Farm
R23
Holland Dike
New Cut
Sadland Farm
Ppg Sta
R1
Five Willow Wath Farm
Head Dike
Five Willow Wath Bridge
Glebe Farm
R2
Fenside
Vine Farm
R25
White House Farm
R3
Crab Lane
Catchwater Drain
Heckington Fen
Labour in Vain Drain
R24
Sidebar Lane
Settlement
Home House
R4
R5
Sandlees Lane
B1395
R6
Elm Grange
R7
Piggery
T1
T2
T3
T4
T5
T6
T7
T8
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T10
T11
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T17
T18
T19
T20
T21
T22
Six Hundreds
Six Hundreds Farm
Six Hundreds Drove
Mown Rakes
R17
College Farm
TON CP