Wind Farm Noise Statutory Nuisance Complaint Methodology.

Report Prepared for Defra: Contract No. NANR 277

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This report is based on earlier work by ARM Acoustics that has been edited and updated by Dani Fiumicelli and Nigel Triner of AECOM; with assistance from Defra Technical Advisers.

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1 Executive Summary

1.1 Executive Summary

This work was commissioned to examine the use of Statutory Nuisance to deal with wind farm noise complaints when resolution via the Planning System is not possible or has proven to be ineffective.

After this Executive Summary,

Section 2 provides:

- an introduction; and
- describes the aim of the study.

Section 3 reviews literature covering:

- wind turbine noise generation,
- established methods of measuring and rating wind farm noise,
- characteristics of wind farm noise,
- noise and health,
- the subjective response to wind farm noise and factors that influence those responses.

Section 4 provides a legal review of statutory nuisance and associated law including:

- the relationship between planning law and statutory nuisance,
- an update of statutory nuisance case law,
- discusses “best practicable means, and;
- drafting abatement notices.

Section 5 introduces,

- a complaint investigation framework and information on planning an investigation,
- the importance and use of:
  - meteorological data
  - non - acoustic data, and;
  - acoustic data.
- comments on data analysis and Interpretation, and;
- examines cumulative impacts from more than one wind farm.

Local Authorities have a legal duty to investigate complaints of Statutory Nuisance, including those that relate to noise from wind farms and wind turbines. Some stakeholders have reported that there can be difficulties in undertaking such investigations and have suggested that further guidance is required.

There is research into the impacts of noise from wind farms which suggests that elements of the nature and character of some of the sounds emitted may aggravate the impact compared to other noise sources and, decibel for decibel, for some people wind turbine noise can be more annoying than other sources. However, it is clear that in common with other noise sources, non-acoustic factors play a significant role in the impact of wind farm noise and a robust dose-response for wind turbine noise is yet to be established.

Planning controls may offer greater protection of residential amenity than can be achieved via Statutory Nuisance as the latter only covers unreasonable material interference with use of property or personal comfort in England, Wales and Northern Ireland and matters that are more than ordinarily tolerable in Scotland; or are injurious to health in all jurisdictions. Additionally, the nuisance limb of Statutory Nuisance is subject to a “Best Practicable Means” defence that can permit a nuisance to continue provided reasonably practicable measures have been used to counteract the nuisance.

Notwithstanding that schemes approved at national level may have a defence against nuisance action, the investigation of complaints of Statutory Nuisance due to noise from wind farms is not constrained by the planning system.

Compliance with any imposed planning conditions does not on its own provide a defence against alleged Statutory Nuisance or justify an effect that is judged to be a Statutory Nuisance due to noise from wind farms and turbines. However, the granting of planning permission affects decisions on Statutory Nuisance where it alters the nature and character of the location so that such noise is to be expected or tolerated. Furthermore, compliance with planning conditions does not provide blanket protection against Statutory Nuisance.

Investigation of complaints of Statutory Nuisance due to noise from wind farms and turbines needs to be carefully planned on a case by case basis and no single prescriptive method is applicable in all cases. However, a set of fundamental principles common to investigation of all Statutory Nuisance noise complaints applies equally to the investigation of complaints of Statutory Nuisance from wind farms. In addition to these fundamental principles it is strongly suggested that investigation of noise complaints involving wind turbines should include detailed assessment of the weather conditions when complaints arise and during any active phase of the investigation i.e. during noise measurements or observations, as scrutiny of such information can substantially improve the efficiency of investigations and assist in assessing Statutory Nuisance

Although there is no statutory or case law based requirement to include noise measurements in an investigation of Statutory Nuisance, it is suggested that the use of noise measurements as well as subjective observations and evidence from complainants should be considered as part of the investigation of wind farm noise complaints for several reasons, including:

- Providing noise level based information to a wind farm operator may help facilitate a rapid remedial and collaborative response to an initial or informal approach by a local authority, which can sometimes resolve noise problems more quickly than the formal Statutory Nuisance procedure;
- Noise measurements can provide information to support subjective qualitative judgements regarding the presence of an adverse noise impact, and thereby help counteract claims of inconsistency against investigating officers or complainants of unduly high expectations, over-zealousness, inexperience and unreasonableness;
- It is common in cases involving commercial interests that the defence will introduce noise measurements or noise level standards and guidelines as means of justification for the noise, or limiting the degree of mitigation that may be imposed. It can be difficult to challenge such an approach without undertaking comprehensive noise measurements, and/or engaging in critical review of the noise level standards and guidelines used to justify the noise;
- Noise measurements can assist in countering claims that the complainant is unduly sensitive or has unrealistic expectations;

Flow charts outlining the suggested steps for investigating complaints of Statutory Nuisance due to noise from wind farms are provided in Appendix B, C and D to this report. While producing a methodology was an original aim of this project, the study recognises that Statutory Nuisance is a flexible concept and that fixed standards and investigation methods do not apply in all circumstances. This freedom is a valuable part of the Statutory Nuisance system and a 'tick-box' type checklist or some other type of fixed methodology could constrain the requirement to take account of local factors that can be decisive in determining Statutory Nuisance. The flow charts therefore show the factors that Local Authority personnel will need to consider in coming to their decision, without being prescriptive of any particular method or measure as to how those factors are appraised.

The key elements of this report are as follows:

- Planning & Statutory Nuisance regimes are separate, they do not substitute for each other and work in parallel.
- Planning permission does not authorise any subsequent Statutory Nuisance but can change the character of a locality, so something which might prior to a development have been a nuisance, no longer is.
- Compliance with planning controls can avoid Statutory Nuisance but does not provide an automatic defence against the normal test of statutory nuisance. Therefore reasonable steps should be made to investigate complaints about alleged Statutory Nuisance from a wind farm.
- Best Practical Means (BPM) is not relevant to the question of whether Statutory Nuisance exists, but can be important in deciding what an abatement notice requires.
- There are particular features of wind farm noise that need to be borne in mind when investigating complaints

- There is research that indicates that wind farm noise can be more disturbing than ‘ordinary’ industrial or transportation noise.
- Wind farm noise complaint investigation is not easy and needs careful planning, including correlation with meteorological conditions and the operation of the wind farm.
- This document contains up to date case law to help in any assessment of Statutory Nuisance.
- Statutory nuisance can provide a safety net for planning decisions on wind farm noise, but may not be able to achieve the same level of protection.

This report should assist with all these points.

2 Introduction and Project Aim

2.1 Introduction

The installation of wind farms in the UK has gathered pace in recent years in response to the two major energy challenges that the UK government has to tackle – reducing carbon dioxide (CO_2) emissions that contribute to climate change and the need to deliver secure, affordable energy supplies

Some stakeholders have reported that there are difficulties in undertaking an investigation of a complaint relating to noise from a wind farm, and have suggested that further guidance is required.

2.2 Project Aim

The aim of the project is to develop a noise Statutory Nuisance complaints investigation methodology for wind farm installations.

3 Literature Review

This section of the report provides information on published papers on wind farm (WF) noise and human response.

3.1 Wind Turbine Operation and Noise

3.1.1 Operation of a Wind Turbine

The turbines used to capture wind energy and convert it into electricity can range in rotor length from less than a metre to over 80 metres; and can be installed individually or in groups.

In this report the term small or micro wind turbine is used for systems that have rotor diameter of less than 16 metres and which normally supply power direct to a specific user, community or development (although some have arrangements to divert excess energy to wider local or national electricity grids)

In this report the terms wind farm or macro-turbine are defined as a group of, or an individual, large scale Wind Turbine Generators of greater than 16 metres rotor diameter, installed in the same region and all operated by the same operator. Normally wind farms provide power to the public at large via the local or national electricity grid; although there is an increasing trend for large scale turbines to be used singly or in small groups to service individual large scale developments e.g. ports, industrial complexes and large factories and campus universities.

A wind turbine produces electricity by harnessing the kinetic energy of wind passing over rotor blades to exert a turning force and drive a generator. The generating capacity of a turbine is principally determined by the diameter of the rotor blades, with larger blades having a greater ‘swept’ area and energy output (a doubling of rotor diameter provides an approximately four-fold increase in power); with the available wind energy being a function of the wind speed (typically the energy increases by approximately eight-fold for a doubling of wind speed). Most wind turbines begin generating electricity at “cut – in” wind speeds of 3-4m/s, generate maximum ‘rated’ power at approximately 8-10m/s and are shut down at wind speeds of 20-25m/s in order to prevent damage.

The majority of large wind turbines producing electricity for the national grid are presently up-wind, three-bladed, horizontal-axis, constant speed systems. Up-wind turbines are designed such that the blades are always upwind of the tower and nacelle, reducing the effects of turbulent airflow from the tower which may otherwise be introduced – this orientation is maintained by the yaw mechanism, which uses electric motors to rotate the turbine – see Figure 1. This is important because where the orientation of the rotor is not directly into the wind, significant bending forces may be introduced into the blades; reducing power generation and potentially leading to mechanical stresses and damage to the system.

In a constant speed system the turbine rotation is regulated, typically in the range 25 to 30 rpm, irrespective of wind speed. Twin speed machines have the ability to operate at a reduced or fixed speed under certain wind conditions, potentially reducing the level of noise emission. Variable speed machines, meanwhile, change speed continuously in response to the wind speed. Direct drive machines have recently been introduced into the market, removing the need for a gearbox and drive train and therefore some of the principal sources of mechanical noise associated with turbines have also been eliminated.

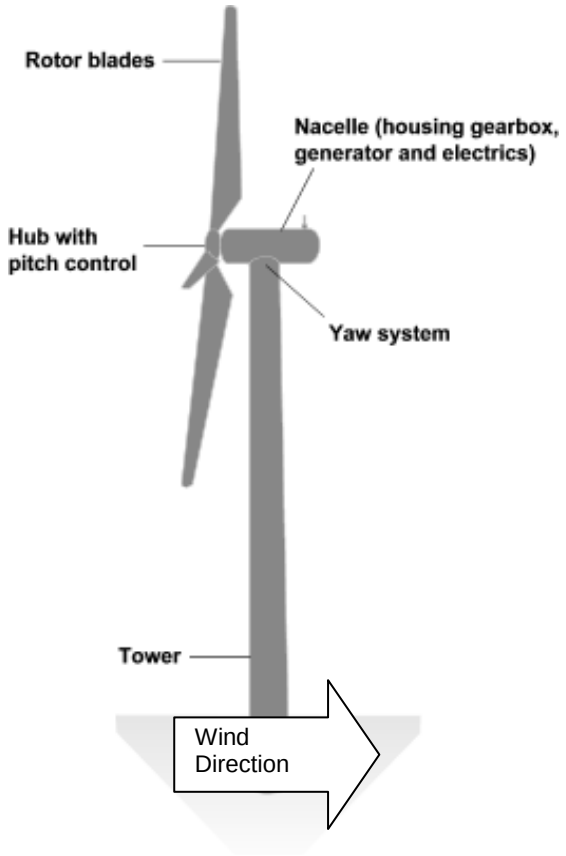

Figure 1 Basic Components of an Upwind Turbine

The turbine will also have a system for regulating its power capture over the range of wind speeds. Below cut-in wind speed there is insufficient energy in the wind for the turbine to generate electricity. Between cut-in wind speed and that at which the rated power is achieved, the wind turbine will attempt to maximize the energy capture from the wind (Region 'A' as illustrated in Figure 2 below). Between the rated wind speed and cut-out (Region 'B') a wind turbine is required to limit the energy capture from the wind, such that the rated power is not exceeded. Above the cut-out wind speed the wind turbine must stop and park the rotor in order to protect itself.

Two principal means are used to regulate the power output: pitch control; or stall control. Pitch control systems, as the name suggests, achieve control by continuous adjustment of the blade angle using either hydraulics or servomotors, so that the maximum power output is maintained at all wind speeds. Stall control systems utilize the inherent aerodynamic properties of the blade, with the profile being designed

so that turbulence is generated by the blade whenever the wind speed becomes too high - increased turbulence reduces the energy conversion and in consequence the power output. Stall control machines also have brakes on the blade tips in order to bring the turbine to a stop. Recent designs have included passive stall systems, wherein the blades have some pitch control at low wind speeds, whilst at high wind speeds (where excess power may be generated) the blade angle will be increased leading to a stall condition. Some of the advantages of such a system are that the power output at high wind speeds can be controlled more accurately and that these machines can be operated at almost the rated power over a large range of wind speeds.

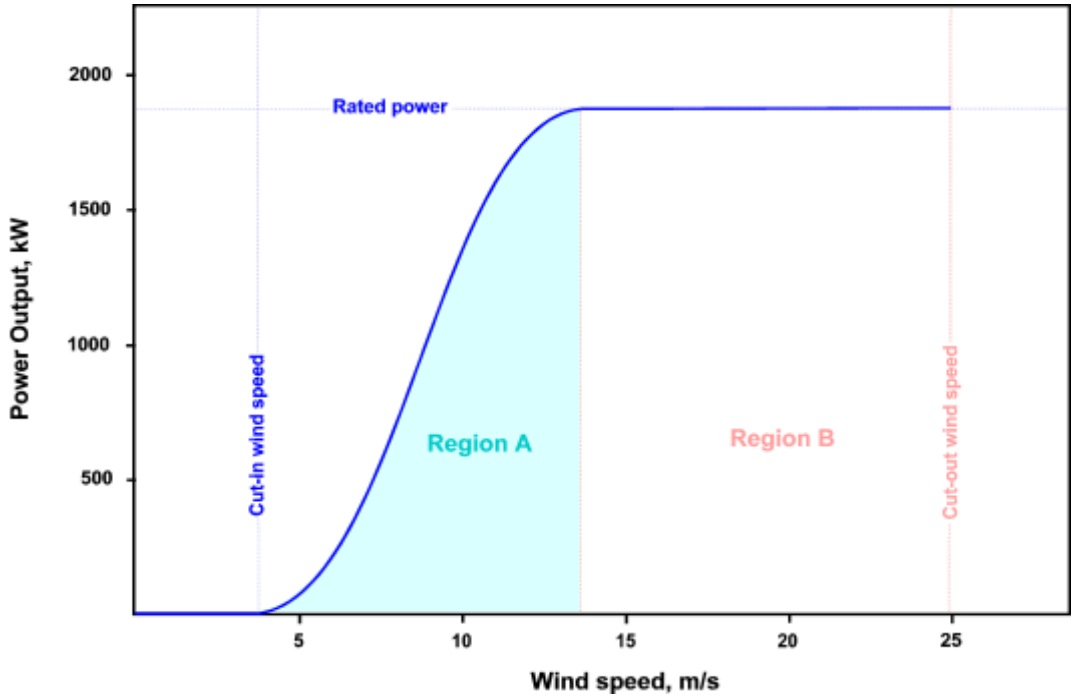

Figure 2 Typical relationship between wind speed and power output (from PPS 22 Companion Guide)

Rotor blades of modern commercial turbines may be of 80m or more in diameter and are typically constructed from glass fibre reinforced polyester or epoxy and wood-epoxy composites. The profile of the blade design will be dependent upon the type and size of the turbine, with the desired lift / stall characteristics and bending strength being of prime importance.

The tower of the wind turbine carries both the nacelle and the rotor. Large wind turbines generally utilise tubular steel towers, although lattice towers or concrete towers may also be employed. Guyed tubular towers are only used for small wind turbines. The height of the tower is a fundamental consideration in

the design; the effects of wind shear can mean that wind speed can increase with height above the ground and with it the available energy.

The power from the rotation of the wind turbine rotor is transferred to the generator through the power train, i.e. through the main shaft, the gearbox and the high speed shaft. The gearbox is used to convert between the slowly rotating, high torque power generated by the wind turbine rotor and high speed, low torque power required for the generator. The gearbox in a wind turbine generally has a single gear ratio between the rotation of the rotor and the generator. The wind turbine generator converts mechanical energy to electrical energy. The generators used within wind turbines must be designed to cope with the fluctuating nature of the mechanical power supplied by the turbine. For large wind turbines (above 100-150 kW) the voltage generated by the turbine is usually 690 Volt three-phase alternating current. This is subsequently passed through a transformer to raise the voltage to somewhere between 10,000 and 30,000 volts, depending on the standard in the local electrical grid.

Cooling of generators is generally achieved using air cooling by ducted fan; although water cooled systems are available. Water cooled generators may be built more compactly, which also gives some electrical efficiency advantages, but they require a radiator in the nacelle to get rid of the heat from the liquid cooling system.

The wind turbine controller consists of computers which operate the various control systems, continuously monitor the condition of the wind turbine and collect detailed statistics on its operation. Improved control strategies are largely responsible for the increase in efficiency of energy generation of wind turbine achieved in recent years. Control mechanisms can also be adapted to specific operational strategies related to the local wind climate, thereby optimising performance, preventing damage or reducing noise which may occur under irregular weather conditions.

Where a number of wind turbines are located in close proximity, it is necessary to ensure that the separation distance between them is adequate to prevent significant wind shadowing which may potentially reduce the energy output. Typically the distance between turbines would be between 3-10 rotor diameters depending upon the direction of the prevailing wind. The direction of rotation of wind turbine blades is generally common for all turbines within a development.

3.1.2 Components of Wind Turbine Noise

The sources of noise emitted from operating wind turbines can be divided into two categories: mechanical; and aerodynamic. The primary sources of mechanical noise are associated with the drive train and the generator, whilst aerodynamic noise is produced by the flow of air over the blades. A summary of each of these noise mechanisms follows.

3.1.2.1 Mechanical Noise

Mechanical noise originates from the relative motion of the various mechanical components and their dynamic response. Sources of such noise include:

- Gearbox

- Generator
- Yaw Drives
- Cooling Fans
- Auxiliary Equipment (e.g. hydraulics)

The mechanical components which are likely to be the source of mechanical noise are generally located within the nacelle. The character of the noise generated may be similar to that from other types of rotating machinery, and can include audible tone(s) in addition to a broadband component. For example, pure tones can be emitted at the rotational frequencies of shafts and generators or the meshing frequencies of the gears. Mechanical noise is generally brought about by the transmission of vibration into the structure of the turbine which is subsequently re-radiated as airborne noise.

Whilst mechanical noise was prevalent in early wind turbines, modern designs have significantly reduced the presence of both broadband mechanical noise and tones to the extent that these have essentially been eliminated as a problem. Increases in mechanical noise may however arise if there is a mechanical fault, such as worn bearings within the gear box/generator, worn teeth within the gear box, or misalignment of the generator drive shaft. In the absence of mechanical fault, however, noise emission from modern wind turbines tends to be dominated by aerodynamic noise.

3.1.2.2 Aerodynamic Noise

A study in 2005[1] looked at localising and quantifying the noise sources on a turbine. The study concluded that:

"*These results clearly show that, besides a minor source at the rotor hub, practically all noise (radiated to the ground) is produced during the downward movement of the blades. The noise is produced by the outer part of the blades (but not by the very tip), and blade noise levels scale with the 5th power of the local flow speed.*"

The figure 3 below clearly shows how blade noise dominates emissions from a modern turbine.

[1] *Oerlemans S, Lopez BM, Localisation and quantification of noise sources on a wind turbine, Wind Turbine Noise: Perspectives for Control Berlin 17th and 18th October 2005*

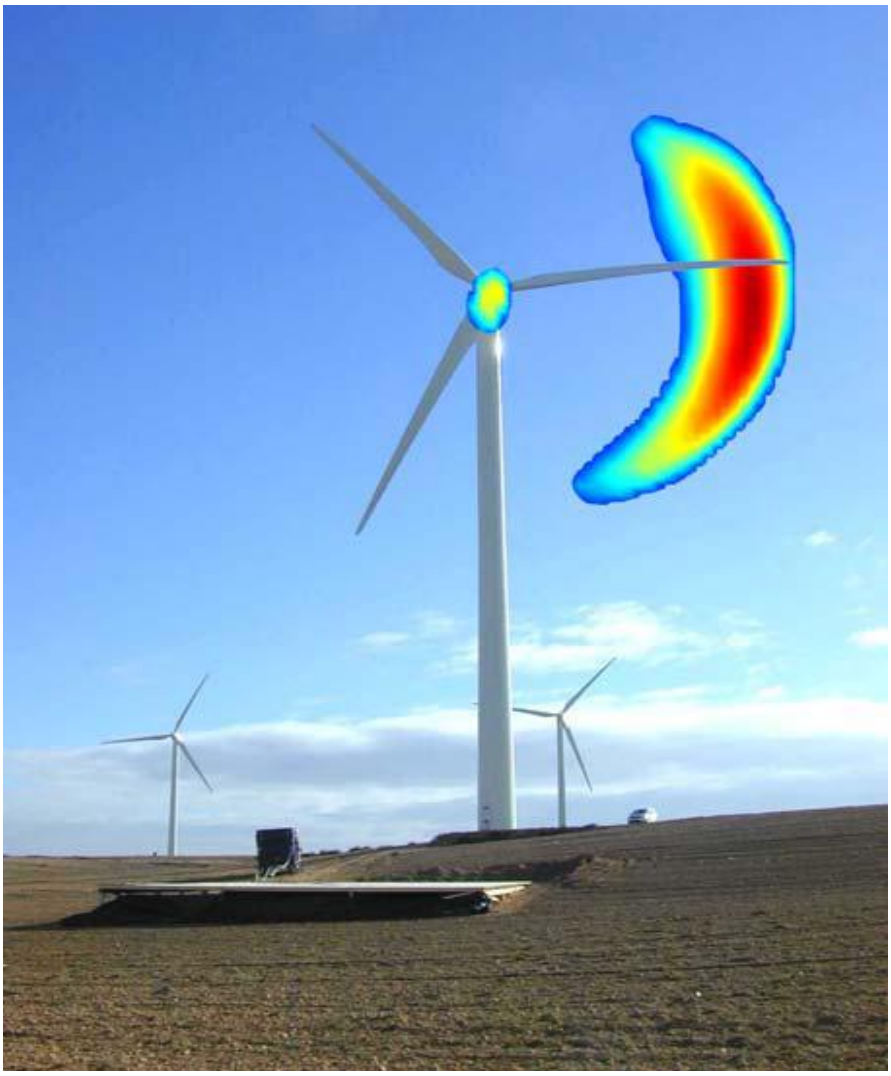

Figure 3 Test set-up with G58 turbine and microphone array platform. The noise sources in the rotor plane (averaged over several rotations) are projected on the picture - Oerlemans S, Lopez BM, Localisation and quantification of noise sources on a wind turbine, Wind Turbine Noise: Perspectives for Control Berlin 17th and 18th October 2005

Aerodynamic noise, which is typically the dominant component of noise from modern wind turbines, originates from the flow of air around the blades and is generally broadband in character. It is directly linked to the production of power and therefore its generation is, to some extent, inevitable - even though it may be minimised by altering the design of the blades.

As shown in Figure 4 below, a number of complex flow phenomena occur around the blades, each of which has the potential to generate noise.

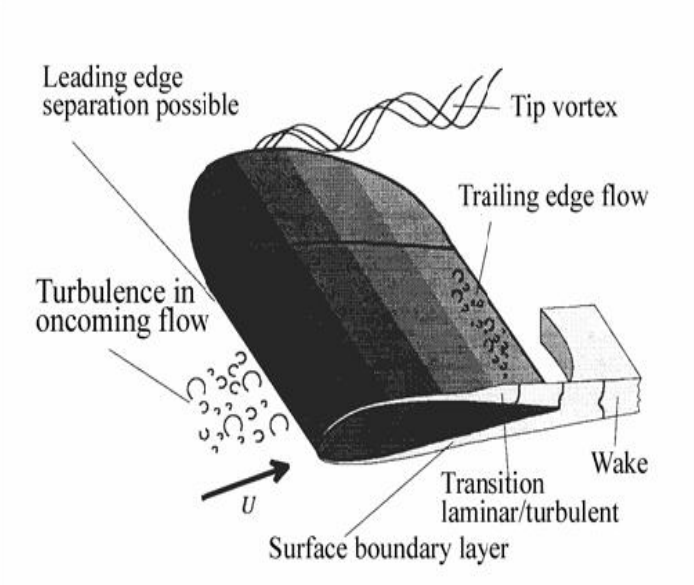

Figure 4 Airflow around a turbine blade. From: S. Wagner, R. Bareiss & G. Guidati, 1996, Wind Turbine Noise - May 1996 by Springer-Verlag Berlin and Heidelberg GmbH & Co. K (ISBN13: 9783540605928)

The principal mechanisms for the generation of aerodynamic noise are shown below in Table 1 and are divided into three groups:

i. Low Frequency Noise - This type of noise is generated when the rotating blade encounters localized flow deficiencies due to the flow around a tower for downwind turbines, wind speed changes, or wakes shed from other turbines.

ii. Inflow Turbulence Noise - Atmospheric turbulence results in local pressure fluctuations which enter into the blade region and generate inflow turbulence noise as the blades chop through them.

iii. Airfoil Self Noise - As air flows over the surface of the blades, turbulence is generated close to the surface at the boundary layer. This boundary layer turbulence generates noise, particularly when it interacts with the trailing edge of the blade, which is therefore known as trailing edge noise - this is often the principal noise generating mechanism on wind turbines. Other types of turbulence are the vortices shed from the tip which generate ‘tip noise’ or from the trailing edge of the blade. Trailing edge vortices are stronger for blunt trailing edges and the associated noise is therefore called blunt trailing edge noise. These noise sources are typically broadband in nature, although tonal components may occur due to blunt trailing edges, or flow over slits and holes.

Table 1: Mechanisms of Aerodynamic Noise

Type or indication	Mechanism	Main characteristics and importance
Low-frequency noise		
Steady thickness noise; steady loading noise	Rotation of blades or rotation of lifting surfaces	Frequency is related to blade passing frequency, not important at current rotational speeds
Unsteady loading	Passage of blades through tower	Frequency is related to blade noise velocity deficit or wakes passing frequency, low intensity in cases of modern upwind turbines; but possibly a contributing factor in cases where a turbine causes turbulent wake to turbines downwind of its location
Inflow turbulence noise		
	Interaction of blades with atmospheric turbulence	Contributing to broadband noise; not yet fully quantified
Airfoil self-noise		
Trailing-edge noise	Interaction of boundary layer turbulence with blade trailing edge	Broadband, main source of high frequency noise (770 Hz < f < 2000 Hz)
Tip noise	Interaction of tip turbulence with blade tip surface	Broadband; not fully understood
Stall, separation noise	Interaction of turbulence with blade surface	Broadband
Laminar boundary layer noise	Non-linear boundary layer instabilities interacting with the blade surface	Tonal, can be avoided
Blunt trailing edge noise	Vortex shedding at blunt trailing edge	Tonal, can be avoided
Noise from flow over holes, slits and intrusions	Unstable shear flows over holes and slits, vortex shedding from intrusions	Tonal, can be avoided

Source: S. Wagner, R. Bareiss & G. Guidati, 1996, Wind Turbine Noise - May 1996 by Springer-Verlag Berlin and Heidelberg GmbH & Co. K (isbn13: 9783540605928)

Of the above mechanisms, inflow turbulence, trailing edge noise, tip noise and blunt trailing edge noise, account for the majority of the noise from wind turbines, although on modern design blunt trailing edge noise is not a significant effect.

Other types of turbulence may also generate noise, but can be avoided. A condition known as ‘stall’ may occur and indeed is used to regulate rotational speed and power generation for some designs. This can generate noise up to 10 dB higher than without stall; however, manufacturers are increasingly moving away from stall-regulated machines, particularly for those of higher power - one of the main reasons for this trend being the higher noise levels they generate.

Another possible cause of noise is flow over imperfections in the blade surface. For example, damage due to holes in blades has been known to cause strongly noticeable tones. There have even been cases of materials (nuts and bolts) being left in the blade to rattle around and of “whistling” from openings in the blades being left exposed (screw fixing holes). For large wind turbines with good manufacturing quality control, such imperfections would be considered a fault condition.

The frequency of the noise generated depends on the size of the turbulent eddies; broadly speaking large eddies produce low frequency noise and small eddies generate higher frequencies. Aerodynamic noise is generally both broadband i.e. it does not contain a distinguishable note or tone, and is of random character, such as exhibited in white noise. The dominant character of the combined aerodynamic noise as described above is therefore a ‘swish’, which is familiar to most people who have stood near to a large wind turbine.

Aerodynamic noise generation is very sensitive to speed of translation at the tip of the blade. To limit its generation, modern, large wind turbines restrict the rotor speeds to ensure that the tip speed remains below 65 m/sec or thereabouts. Large, variable speed wind turbines often rotate at slower speeds in low winds, increasing in higher winds until the limiting rotor speed is reached. This results in much quieter operation in low winds than a comparable constant speed wind turbine.

Other means of reducing aerodynamic noise are associated with the design of the blade – such as lower angles of attack and the use of modified trailing edges - which have become more efficient, causing a greater proportion of the wind energy to be converted into rotational energy and less into acoustic noise.

3.2 ETSU-R-97 The Assessment and Rating of Noise from Wind Farms (DTI 1996)

The report ETSU-R-97 is used throughout the UK to assess wind farm noise in planning applications.

ETSU-R-97 was written by a Noise Working Group of developers, noise consultants, environmental health officers and others set up in 1995 by the Department of Trade and Industry through ETSU (the Energy Technology Support Unit).

The preface to ETSU-R-97 says:

"*The aim of the Working Group was to provide information and advice to developers and planners on the environmental assessment of noise from wind turbines. While the DTI facilitated the establishment of this Noise Working Group this report is not a report of Government and should not be thought of in any way as replacing the advice contained within relevant Government guidance. The report represents the consensus view of the group of experts listed below who between them have a breadth and depth of experience in assessing and controlling the environmental impact of noise from wind farms. This consensus view has been arrived at through negotiation and compromise and in recognition of the value of achieving a common approach to the assessment of noise from wind turbines*".

The first paragraph of the executive summary to ETSU-R-97 also says:

"*This document describes a framework for the measurement of wind farm noise and gives 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*."

3.2.1 ETSU - R - 97 In Brief

The technical detail of ETSU-R-97 is important, but can be summarised as follows:

- The guidance requires the predicted noise levels from the wind turbine under a range of wind speeds to be compared with the background noise level at noise sensitive premises under similar wind conditions;
- The guidance advises using the $L_{A90,10\ min}$ noise index for both turbine and background noise; and that the $L_{A90,10\ min}$ of turbine noise is typically 2 dBA less than the equivalent $L_{Aeq,t}$ value.
- Noise limits should be applied to external locations and should apply only to those areas frequently used for relaxation or activities for which a quiet environment is highly desirable;
- Noise limits set relative to the background noise are more appropriate in the majority of cases;
- Generally, the noise limits should be set relative to the existing background noise at the nearest noise-sensitive properties and that the limits should reflect the variation in both turbine source noise and background noise with wind speed;
- It is not necessary to use a margin above background noise levels in particularly quiet areas. This would unduly restrict developments which are recognised as having wider national and global benefits. Such low limits are, in any event, not necessary in order to offer a reasonable degree of protection to wind farm neighbours.
- Separate noise limits should apply for day-time and for night-time as during the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance.
- Absolute noise limits and margins above background should relate to the cumulative effect of all wind turbines in the area contributing to the noise received at the properties in question. Any existing turbines should not be considered as part of the prevailing background noise.

- Noise from the wind farm should be limited to 5dBA above background for both day- and night-time, remembering that the background level of each period may be different, subject to a lower limit of 35 to 40 dBA during the day and 43 dBA at night.
- The $L_{A90,10min}$ index should be used for both the background noise and the wind farm noise, and that when setting limits it should be borne in mind that the $L_{A90,10min}$ of the wind farm is likely to be about 1.5-2.5dBA less than the L_{Aeq} measured over the same period. The use of the $L_{A90,10min}$ index for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.
- A fixed limit of 43dBA is recommended for night-time. This is based on a sleep disturbance criterion of 35dBA with an allowance of 10dBA for attenuation through an open window (free field to internal) and 2dBA subtracted to account for the use of $L_{A90,10min}$ rather than $L_{Aeq,10min}$.
- Both day-and night-time lower fixed limits can be increased to 45dBA to increase the permissible margin above background where the occupier of the property has some financial interest in the wind farm.
- In low noise environments the day-time level of the $L_{A90,10min}$ of the wind farm noise should be limited to an absolute level within the range of 35-40dBA. The actual value chosen within this range should depend upon: the number of dwellings in the neighbourhood of the wind farm; the effect of noise limits on the number of kWh generated; and the duration of the level of exposure.
- For single turbines or wind farms with very large separation distances between the turbines and the nearest properties, a simplified noise condition may be suitable. If the noise is limited to an $L_{A90,10min}$ of 35dBA up to wind speeds of 10m/s at 10m height, then this condition alone would offer sufficient protection of amenity, and background noise surveys would be unnecessary.

ETSU-R-97 was originally published in 1996 and has been used extensively since then. The Working Group suggested that the report and its recommendations be reviewed 2 years after publication. A formal review did not occur but it is understood that ETSU-R-97 is kept under consideration by the government. The Government accepted the document when PPS 22 was adopted in England; and equivalent policy and advice has been adopted in the devolved administrations[2].

3.3 New technical factors for use in assessing Wind Farm impacts

Some of the members of the original Noise Working Group on wind farm noise, which drafted ETSU-R-97, and others who have often advised on opposing sides during public inquiries, gathered in order to build on experience and knowledge gained during the period since the adoption of ETSU-R-97. They also aimed to settle a number of disputes about the factors that should be taken into account when assessing wind farm noise. Their thoughts were published in an article in the Institute of Acoustics Bulletin, Vol 34 No 2, March/April 2009; which can be summarised as follows:

[2] The regulation of wind turbine noise varies across the EU, some countries have specific policies to regulate noise from wind farms, others treat noise from wind farms the same as for other sources of noise. The specific policy and advice documents for England, Scotland, Wales and Northern Ireland are discussed later in the report.

- Wind naturally exhibits a ‘shear effect’. That is, wind speeds increase with increasing height above the ground. Thus the wind speed at a typical wind turbine hub height of more than 50m can be higher than that at 10m. This height is used here as an example because the various standards used to assess wind farm noise and wind turbine sound outputs, including ETSU-R-97, tend to relate all results to the wind speed at 10m height. Typically this is done by assuming a ‘standardised’ wind shear to convert between turbine hub height wind speeds and the wind speed at 10m height. Consequently, under specific wind shear conditions the hub height wind speed may be underestimated, and as a result the wind turbine source noise levels may also be underestimated at any given 10m height wind speed. However, the actual wind shear seen on any specific site may deviate from the assumed ‘standardised’ shear. The actual shear will depend both on the ‘roughness’ of the ground (influenced by, for example, vegetation or topography) and also the ‘stability’ of the atmosphere (influenced by the cooling/heating effect of the ground on the air above it). (See also 3.6 below)
- Due to potential difference in wind speed at different heights above the ground, the background noise levels should be correlated with derived (not measured) 10 m height wind speeds. One method for doing this is described in the IoA article. Effectively, the result of adopting this procedure is to reference all noise levels (both background and turbine) to the wind speed at turbine hub-height. The effect of such a procedure is to move the derived background noise regression curve to the left i.e. for any given wind speed, the correlated turbine noise level will be higher than the equivalent value for wind speed measured at 10m height. It should be noted that the scatter of data is often greater compared to the ETSU-R-97 method of referencing background noise levels at the receptor to 10 m height wind speeds at the scheme site; because wind speed at hub height will have less influence on background noise levels at the receptor compared to wind speeds at a height of 10 m or lower. This method effectively adjusts the background noise level at the receptor downwards to reflect the influence of wind shear on the turbine noise propagation. However, the method detailed in the IOA article relies on wind shear data gathered during the background noise survey; the duration of which may be appropriate to establish prevailing background noise levels, but may not be long enough to gather representative data about wind shear. It is important to note that whilst the article only describes one method for dealing with wind shear in detail, it specifically allows for other methods to be used to account for wind shear, provided they are fully explained and justified by the user. One alternative that has been accepted by planning inspectors is to use historical data regarding wind shear from any long term i.e. 6 to 18 months, wind resource survey at the site, typically utilising a 60m mast and multiple anemometers. This data is then used to correct the noise output of the turbine to account for typical wind shear at the site.
- The group agreed that the preferred method of predicting the propagation of wind turbine noise is ISO 9613-2; and that in using this standard:
  - The turbine sound power levels used as input to the propagation model should be supported by documentation from the manufacturer with a statement of their status.

- The atmospheric conditions used in the calculation should be assumed as temperature of 10^0C and 70% Relative Humidity.
- The assumption of soft ground should not be made, and ground absorption G should be in the range 0 ("hard" ground) to 0.5 (mixed "hard/soft ground").
- Generally no account should be taken of barrier attenuation by land form unless there is no line of sight between the top of the rotor and the receiver, when normally a maximum attenuation of 2 dBA can be used. Any higher barrier attenuation must be fully justified.

- Agreement was also reached that there is no robust evidence that low frequency sound, infrasound and ground-borne vibration from wind farms, generally has adverse effects on neighbours[3].

3.4 Amplitude Modulation of Aerodynamic Noise (AM)

The sound level from turbine blades is often not completely steady, but is modulated (fluctuates) in a cycle of increased and then reduced level, sometimes called "*blade swish*", typically occurring at a rate of around once or twice per second. In the majority of installations the modulation depth may be up to 2-3 dBA, which was regarded as being acceptable by the ETSU working group[4]. In some situations, however, the modulation depth increases to the point where it can become more pronounced[5] and potentially give rise to increased annoyance[6]. This phenomenon is known as amplitude modulation of aerodynamic noise or more succinctly by the acronym AM.

In early wind turbine designs, where the rotor was positioned downwind of the tower, a pronounced 'thump' was possible as each blade passed through the turbulent wake shed from the tower. However, this effect does not exist for the upwind rotor designs found on the majority of modern wind farm developments. Instead, it seems that aerodynamic modulation is due to fluctuation in the strength of some of the other mechanisms of aerodynamic noise described in Table 1 above.

Aerodynamic noise generation depends primarily on the rotor tip speed, but there is also some dependence on wind speed. Therefore, if wind speed is not even across the rotor plane i.e. wind shear, then some fluctuation in level can be expected as the blade turns; where this effect occurs it may be more significant for large scale turbines, as it is likely to intensify with increasing rotor size. Under stable atmospheric conditions, as can occur at night time, where the difference in wind speed between the top and bottom of the rotor can be relatively high, such a mechanism may give rise to a significant cyclical fluctuation in turbine noise level.

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[3] For example as concluded in the Hayes Mckenzie report, "The measurement of low frequency noise at three UK wind farms", Hayes Mckenzie Partnership Ltd, report to the Department of Trade and Industry (2006) – see http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/energy/sources/renewables/explained/wind/onshore-offshore/page31267.html (last viewed 8th March 2011)

[4] *ETSU–R-97 page 67, third paragraph.*

[5] *For example, work more recent than ETSU-R-97 suggests that AM of 3 dB to 5 dB from multiple turbines has been detected, and postulates that AM of potentially 6 to 10 dB is possible from multiple turbines in very stable atmospheric conditions - G.P. Van Den Berg, The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines, Journal of Low Frequency Noise & Vibration and Active Control, Volume 24, Number 1 / March 2005*

[6] *E. Pedersen and K. Persseon Waye, "Perception and annoyance due to wind turbine noise–a dose-response relationship", Journal of the Acoustical Society of America, 116 (6), 2004, 3460-3470*

Whilst all the causes are not known, it appears that AM tends to occur under certain meteorological conditions and the limited evidence available suggests this effect is likely to be manifest at a minority of wind farms. Moreover, it is a highly technical area, which despite research by numerous investigators over the last 20 years; there is to date no universally accepted explanation as to the causes of AM or means to predict its occurrence.

3.4.1 Low Frequency Noise and AM

Two studies completed on behalf of the then Department of Trade and Industry that are relevant to AM. The first study was not directly related to AM as it investigated the issues around possible low frequency noise from wind farms[7], in response to allegations of health effects associated with alleged low frequency noise from wind farms. This study indicated that wind farms are not significant sources of low frequency noise. However, it did highlight that in a minority of locations under very specific circumstances the noise generated by a wind farm can be altered i.e. become modulated, to take on a "*beat*" like character with a periodicity as low as one to two beats per second. It was this slow "*beat*" that was being interpreted as low frequency noise, but the frequency of the generated turbine noise was actually well above what would usually be considered to be low frequency.

The second study focused specifically on the issue of AM of wind farm noise and concluded that this was an infrequently occurring phenomenon tending to arise under very specific meteorological conditions. This research, undertaken by Salford University in 2007[8], found that out of 133 operational wind farms investigated, 27 were associated with complaints; but AM was considered to be a factor in noise complaints at only four sites and a possible factor in a further eight locations.

Some researchers, and objectors to wind farms and campaigning groups[9] have queried the conclusions drawn in regard to the occurrence of AM in the Salford University report, and have suggested that it is more frequent than claimed in the study.

However, it appears clear that whatever the actual number of occurrences of AM, it only occurs at a minority of wind farm sites for some of the time.

ETSU-R-97 recognises a potential for AM of up to 3 dBA (i.e. the noise level goes up and down by 3 dBA in each blade rotation) and ETSU-R-97 states that it takes such a degree of "blade swish" into account in the noise limits it recommends (recommendation 27 in the ETSU-R-97 summary). However the document does not include a specific penalty for AM, beyond a 2 dBA adjustment in setting the fixed noise limit for low wind speeds.

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[7] *Hayes Mckenzie, "The measurement of low frequency noise at three UK wind farms", Hayes Mckenzie Partnership Ltd, report to the Department of Trade and Industry (2006)*

[8] *A. Moorhouse, M. Hayes, S. von Hünerbein, B. Piper, M. Adams, "Research into Aerodynamic Modulation of Wind Turbine Noise", URN 07/1235, University of Salford and Department for Business, Enterprise & Regulatory Reform, UK (2007).*

[9] *Renewable Energy Foundation Wind Turbine Noise Complaint Data 1/5 - http://www.ref.org.uk/Files/jc.lm.salford.data.comment.07.02.09.c.pdf (Last viewed* 8th March 2011*)*

3.4.2 Potential factors influencing AM

Whilst it is not yet possible to accurately predict the occurrence of AM, is has been concluded that it is "*likely to occur where there is a combination of high wind shear, wind direction, and close proximity of turbines to one another*."[10]

Recent work by F Van Den Berg in commenting on the findings of other authors concluded that[11]:

- "*Amplitude variations can occur downwind from single wind turbines and wind farms, and can be observed at distances up to approximately one km and perhaps more.*
- *Spectral analysis of the variations in the sound level at dwellings due to a single or to multiple wind turbines show that the variations occur in frequency bands from 100 to 2000 Hz, but are strongest at 500 to 1000 Hz.*[12]
- *The dominant source at these frequencies is turbulence at the trailing edge of the blades. Di Napoli found similar variations at a position 530 m downwind from a single wind turbine.*[13]
- *Hayes*[14] *investigated the low-frequency character of wind turbine sound as a possible cause of increased annoyance at three wind farms, but concluded that the regular variations of the sound level were a more likely cause. He showed that the variations in broad-band A-weighted sound level (approximately 2 dB) were less pronounced than the variations in the 250, 315 and 400 Hz 1/3 octave band level (approximately 8 dB), with a modulation frequency equal to the blade passing frequency. Variations in other 1/3 octave bands were less strong*.".

However it should be noted that the phenomena of turbulence and the related mechanisms of noise generation associated with wind turbines, are not fully understood and that there are presently no peer reviewed and validated models available through which the occurrence of AM can be reliably predicted.

3.5 Measurement of AM

The measurement of AM is not easy, not least because there is no universally accepted definition of AM or standardised methodology for its measurement.

For example, recent work[15] demonstrates the complexities in measuring AM with the following comments in regard to common methods to measure amplitude modulation using direct measurement of modulation depth i.e. peak to trough height of the time varying signal.

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[10] *Report to Secretary of State ref No APP/W0530/A/07/2059471: Appeal by RES Developments against South Cambridgeshire District Council; 26th August 2009 – comments by the Inspector.*

[11] *F Van Den Berg, "Why is wind turbine noise noisier than other noise?, Proceedings of Euronoise, Edinburgh, October 2009*

[12] *GP Van Den Berg, "The sounds of high winds" (doctoral thesis), University of Groningen (2006)*

[13] *C. Di Napoli, "Case study: Wind turbine noise in a small and quiet community in Finland, proc.3rd Int. Meeting on Wind Turbine Noise, Ålborg (2009)*

[14] *Hayes Mckenzie, "The measurement of low frequency noise at three UK wind farms", Hayes Mckenzie Partnership Ltd, report to the Department of Trade and Industry (2006) – see* http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/energy/sources/renewables/explained/wind/onshore-offshore/page31267.html *(last viewed* 8th March 2011*)*

[15] *Seunghoon Lee, Kyutae Kim, Seungmin Lee, Hogeon Kim and Soogab Lee, An estimation method of the amplitude modulation in wind turbine noise for community response assessment, Third International Meeting on Wind Turbine Noise Aalborg Denmark 17 – 19 June 2009*

"*In this method, modulation depth is determined by the difference between Lmax and Lmin from a spectrogram or A-weighted sound pressure level with time weighting F. Since this procedure should be treated manually, this method cannot be applied for a long time measurement, which is required for community response assessment. Another method employs percentile sound levels instead of Lmax and Lmin. This method defines modulation depth as the difference between L5 and L95. In [this method], one-third octave band spectral modulation depth was obtained by the method. However, it can be applied only when the overall sound level does not gradually increase or decrease. Legarth proposed that fluctuation strength can be a metric for amplitude modulation in wind turbine noise. However, since a model of fluctuation strength is based on temporal variation of a masking pattern scale of fluctuation strength [which] is too large to measure amplitude modulation in wind turbine noise. Fluctuation strength is almost zero until a modulation depth of about 3 dB which is a common modulation depth for wind turbine noise*."

The authors of the above comments go on to describe a complex AM assessment method based on the Fast Fourier Transform narrow band frequency analysis of sound recordings; which unfortunately is unlikely to be practicable in most complaint investigation situations.

Although the potential occurrence of AM has been routinely raised by objectors to wind farm schemes, many planning inspectors have regarded AM as simply an additional risk, albeit of low probability, and have not specifically refused planning permission or felt the need to apply conditions due to the potential of AM to occur. However, in regard to wind turbine AM, at least one Planning Inspector[16] has adopted the following planning condition, which had been proposed by objectors.

"*Amplitude modulation is the modulation of the level of broadband noise emitted by a turbine at blade passing frequency. These will be deemed greater than expected if the following characteristics apply:*

a) A change in the measured $L_{Aeq,125\ milliseconds}$ turbine noise level of more than 3 dB (represented as a rise and fall in sound energy levels each of more than 3 dB) occurring within a 2 second period.

b) The change identified in (a) above shall not occur less than 5 times in any one minute period provided the $L_{Aeq,1\ minute}$ turbine sound energy level for that minute is not below 28 dB.

c) The changes identified in (a) and (b) above shall not occur for fewer than 6 minutes in any hour.

Noise immissions at the complainant's dwelling shall be measured not further than 35m from the relevant building, and not closer than within 3.5m of any reflective building or surface, or within 1.2m of the ground."

It is suggested that the above method, whilst not simple or easy to implement, may provide a starting point in trying to quantify AM by direct measurement, although it does not represent a validated method of

[16] *Inspectors Report Appeal Ref: APP/Q1153/A/06/2017162 Land to the south east of North Tawton and the south west of Bow (the "Denbrook Inquiry") December 2009. This condition was one of the grounds for a section 288 Town & Country Planning Act review of the Secretary of State's decision to grant planning permission for a wind farm in The Queen on the application of Hulme (claimant) Secretary of state for communities and local government [2010] EWHC 2386 (Admin). But the High Court upheld the condition as being valid as it was accompanied by another condition requiring a monitoring regime and procedure for dealing with complaints to be agreed with the LA.*

assessing the significance of any impact or effect on amenity, and does not constitute a threshold for Statutory Nuisance.

3.6 Wind Shear

Wind shear is the phenomenon whereby wind speed varies at different heights above the ground, typically with wind speed increasing at higher altitudes. Generally, the greater the wind shear the more noise the turbine may generate compared with lower shear conditions. This means that where significant wind shear arises, typical ETSU-R-97 derived wind turbine noise levels which are standardised to wind speeds at 10 m height and do not allow for the wind shear, may underestimate the noise levels at a receptor.

When undertaking noise certification measurements of wind turbine sound power outputs the internationally applicable procedure in IEC 61400-11:2002 is used for the vast majority of major wind turbine suppliers, which applies a standardised means of converting between wind speeds at hub height and 10m height. This involves using a 'standard' roughness length, regardless of what the actual roughness length seen on the test site may have been. This 'normalisation' procedure is adopted to ensure direct comparability between test results for different turbines. However, when this standardised data is subsequently used to calculate the sound power radiated from an installed turbine on an actual wind farm site, it is important to convert between 10m height wind speeds and hub height wind speeds using the actual wind speed differences between these heights experienced on the site itself. These hub height wind speeds may well be different from those calculated by assuming the standard ground roughness length; and unless site specific procedure is used there is a risk that the noise output from the turbines under wind shear conditions may be underestimated.

For example, using wind speed data measured onsite at different heights to calculate effects of wind shear provides site specific data, as effects can vary from site to site and at a particular site from day to day and different parts of the day. This could be done with data from wind speed measurement at different heights on an anemometry mast at the wind farm site or use of LIDAR[17] data.

3.7 Wind turbines Infrasound and Low Frequency Noise

There are many natural sources of infrasound and low frequency noise, including the wind, volcanic eruptions, ocean waves, meteors, and any effect which leads to slow oscillations of the air. Man made sources include road, rail and air transport sources, explosions, large combustion processes, slow speed fans and machinery. Human evolution has been in the presence of natural infrasound and low frequency noise sources and our hearing system adapted so that the human hearing threshold at infrasound and low frequencies is much higher than at mid to high frequencies.

Infra Sound is generally regarded as sound with a frequency of <20 Hz. Normally sound of frequency less than 20 Hz is considered not audible to most people, as the average human hearing threshold is typically substantially above ordinary environmental noise levels at these frequencies. However, should sound levels at frequencies below 20 Hz be abnormally high, then especially sensitive persons can perceive the

[17] *LIDAR = Light Detection and Ranging ; an optical remote sensing technology that can be used for measuring wind speed at different heights.*

sound, and as levels at these frequencies increase then persons with normal hearing may be able to detect the sound. However, "*there is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects*" [18].

However in certain circumstances, Low frequency noise, typically defined as sound in the frequency range from about 20 Hz to 200Hz, has been recognised as a special environmental noise problem[19].

There are four main subjective factors in response to high levels of infrasound and low frequency noise: auditory perception, pressure on the eardrum, perception through vibration of the chest and more general feeling of vibration. Analysis of these responses shows that auditory perception was the controlling factor. That is, although high levels of low frequency noise may produce other sensations, the ear is the most sensitive receptor.

At high levels infrasound and low frequency noise can have similar effects as higher frequency sound e.g. sleep and activity disturbance, annoyance and other health effects. Among the more consistent findings in humans of the effects of infrasound and low frequency noise are changes in blood pressure, cardiac and respiratory rate, endocrine (hormone) response and balance.

It is thought that some early wind turbine types, particularly with downwind configurations, could generate significant infra sound and low frequency noise[20]. But the consensus is that nowadays modern upwind turbines are not sources of substantial infra sound and low frequency noise[21]

However, although wind turbines tend to produce broad band rather than infrasound or low frequency dominated noise, at long distances higher frequencies are reduced compared to low frequencies due to differential attenuation from air and ground absorption etc and can be less readily masked by ambient noise. It is therefore conceivable that lower frequencies may become the distinguishing feature of turbine noise under some circumstances[22].

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[18] Community Noise 1995 Edited by Birgitta Berglund & Thomas Lindvall at para para 7.1.4

[19] Community Noise 1995 Edited by Birgitta Berglund & Thomas Lindvall at para 7.7.9.4

[20] Shepherd, K. P. and H. H. Hubbard (1991). "Physical characteristics and perception of low frequency noise from wind turbines." Noise Control Eng 36(1): 5 -15.

[21] *Hayes Mckenzie, "The measurement of low frequency noise at three UK wind farms", Hayes Mckenzie Partnership Ltd, report to the Department of Trade and Industry (2006) – see* http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/energy/sources/renewables/explained/wind/onshore-offshore/page31267.html *(last viewed* 8th March 2011*)*

[22] Such a phenomenon has been found with sound from some outdoor pop concerts, as noted in guideline 3.4 of the noise council code of practice on environmental noise from outdoor pop concerts and its underpinning research. Here differential attenuation of different frequencies sound caused a frequency imbalance at 2 Km distance from the venue which led to complaints of low frequency noise; whereas there was less of a problem with low frequency dominance closer to the venue, although overall noise levels were higher, as the frequency balance was less skewed towards low frequency sound.

A number of studies[23] have established that conventional methods of assessing noise impact, typically based on A-weighted equivalent level, can be inadequate for characterising noise with a strong low frequency component and lead to incorrect conclusions by regulatory authorities.

There have been a large number of laboratory measurements of annoyance by low frequency noise, each with different spectra and levels, making comparisons difficult, but the main conclusions are that annoyance of low frequencies increases rapidly with level. Additionally these studies confirm that the A-weighted level underestimates the effects of low frequency noises. However, validation of those criteria that have been developed has been for a limited range of noises and subjects.

Professor Geoff Leventhall produced a comprehensive review of Infrasound and low frequency noise for Defra in 2003 (Contract ref: EPG 1/2/50) [24], extracts of which he used in a paper published in 2004[25], and which are reproduced below

"*There have been a large number of laboratory determinations of annoyance of low frequency sounds, mainly measurements using either 'normal' or 'sensitive' subjects. Stimuli have included tones, bands of noise or specially developed spectra. There is, of course, a wide range of possible stimuli, which experimenters have chosen according to their experience of what is required (Adam, 1999; Andresen and Moller, 1984; Broner and Leventhall, 1978; Broner and Leventhall, 1984; Broner and Leventhall, 1985; Goldstein, 1994; Goldstein and Kjellberg, 1985; Inukai et al., 2000; Kjellberg and Goldstein, 1985; Kjellberg et al., 1984; Moller, 1987; Nakamura and Inukai, 1998; Persson and Bjorkman, 1988; Persson-Waye, 1985; Poulsen, 2002; Poulsen and Mortensen, 2002). Some of the laboratory studies have used recordings of real noises as stimuli, whilst others have worked with recordings of the actual noises as experienced by subjects in their own work places or homes. (Holmberg et al., 1993; Landstrom et al., 1994; Manley et al., 2002; Mirowska, 1998; Mortensen and Poulsen, 2001; Poulsen and Mortensen, 2002; Tesarz et al., 1997; Vasudevan and Gordon, 1977; Vasudevan and Leventhall, 1982).*

Most determinations have been aimed at relating the A-weighted level, or some other derivative of the spectrum of the low frequency noise, to its annoyance. Whilst they are adequate studies, and have shown some general factors in low frequency noise annoyance, they are limited in that their results apply only to

[23] E.g. Persson, K., Björkman, M., and Rylander, R. (1990): Loudness, annoyance and the dBA in evaluating low frequency sounds. Jnl Low Freq Noise Vibn 9, 32-45.; Persson, K., and Bjorkman, M. (1988): Annoyance due to low frequency noise and the use of the dB(A) scale. J Sound Vibration 127, 491-497.; Persson, K., Björkman, M., and Rylander, R. (1990): Loudness, annoyance and the dBA in evaluating low frequency sounds. Jnl Low Freq Noise Vibn 9, 32-45.;

Also

The 1995 Guidelines for Community Noise edited by Berglund & Lindval and advise that "*The general use of the A-weighting filter attenuates the low frequencies so that the A-weighted sound pressure level does not reflect the true impact of the noise load*.; Whilst the WHO guidelines for Community Noise from 2000 advise that "" *When prominent low frequency components are present, noise measures based on A-weighting are inappropriate*"

[24] A Review of Published Research on Low Frequency Noise and its Effects Report for Defra by Dr Geoff Leventhall ,Assisted by Dr Peter Pelmear and Dr Stephen Benton See http://www.defra.gov.uk/environment/quality/noise/research/lowfrequency/documents/lowfreqnoise.pdf (Last Viewed 8th March 2011)

[25] Leventhall HG. Low frequency noise and annoyance. Noise Health [serial online] 2004 [cited 2011 Feb 24];6:59-72. Available from: http://www.noiseandhealth.org/text.asp?2004/6/23/59/31663 (last viewed 8th March 2011)

the particular noises investigated, often with a small number of subjects. It is unlikely that continued studies of this kind will result in step changes in our understanding of low frequency noise annoyance. However, Poulsen and Mortensen (2002) are an advance on previous work, as they compare subjective assessments with criteria, which have been developed in some European countries, specifically for assessment of low frequency noise.

A number of criteria have been developed for assessment of low frequency noise. (Broner and Leventhall, 1983; Challis and Challis, 1978; Inukai et al., 1990; Vercammen, 1989; Vercammen, 1992).

In recent years, some European countries have adopted national criteria for low frequency noise, including Sweden ((Socialstyrelsen¬Sweden, 1996)), Denmark (Jakobsen, 2001) Netherlands ((N S G, 1999) Germany (DIN:45680, 1997) , Poland (Mirowska, 2002). Some of these methods assume a threshold curve for limitation of annoyance, based approximately on the ISO226 threshold, or a curve parallel to this threshold, but extended to frequencies below20Hz.

The criteria have been compared under laboratory conditions for some specific noises (Poulsen, 2002; Poulsen and Mortensen, 2002). The noises were judged by 18 otologically normal young listeners and by four older people (41-57 years) who had made complaints of annoyance by low frequency noise. Judgements were made under assumed listening circumstances of day, evening and night. The complaint group rated the noises to be more annoying than the other group did. Overall, the Danish method gave highest correlation between objective and subjective assessments, but only when a 5dB penalty for impulsive sounds was included."

3.7.1 The Salford University/Defra LF Criteria

At the end of their report for Defra, Professor Leventhall and his colleagues indentified a need for further research in the UK to develop its own assessment method as our existing techniques were "*not able to determine its (*LF noise*) nuisance value*".

Subsequently, in 2005 Defra released the report and findings from a study into low frequency noise by Salford University Contract NANR 45[26] which developed:

- Proposed criteria for the assessment of low frequency noise disturbance;
- Procedure for the assessment of low frequency noise complaints, and;
- Field trials of proposed procedure for the assessment of low frequency noise complaints.

The proposed reference curve for the assessment of low frequency noise disturbance from page 12 of the procedure for the investigation of low frequency noise is reproduced below.

[26] See http://www.defra.gov.uk/environment/quality/noise/research/lowfrequency/ (last viewed 8th March 2011)

Figure 5 The proposed Salford University/Defra reference curve for the assessment of low frequency noise disturbance

Table 2 Proposed reference curve

Hz	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
dB, Leq	92	87	83	74	64	56	49	43	42	40	38	36	34

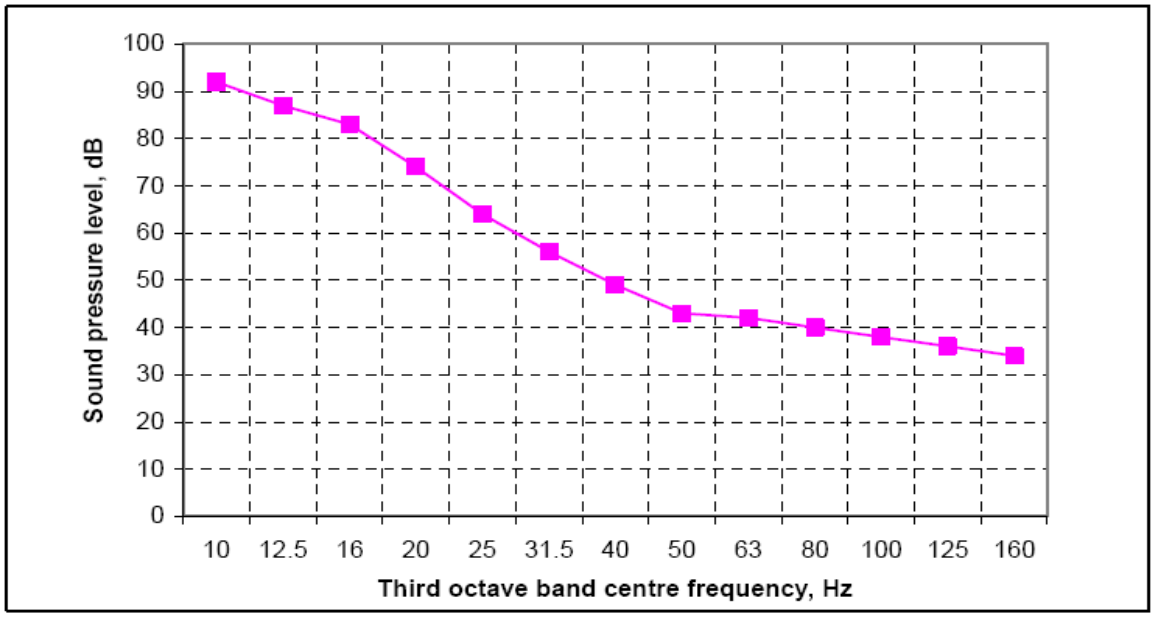

Figure 1 Criterion curve for assessment of low frequency noise

Should local authorities consider that low frequency noise is a substantial element of any complaint, they may wish to consider incorporating the advice of the Salford University Contract NANR 45 procedure for the assessment of low frequency noise into their investigation.

3.8 Practical Noise Control[27]

Effective noise control and with it the prevention, abatement or restriction of noise Statutory Nuisance, is best achieved by using adequate separation of the turbines from noise sensitive receptors, through careful design of the turbines in conjunction with the selection of wind turbines with appropriate noise

[27] *The brief overview of practical noise control in this section is derived from the following reference - Wind Turbine Noise. Wagner, Bariess & Guidati, Springer, 1996; and, Wind Turbine Noise Issues. Rogers & Manwell, 2004, University of Mass. Amherst.*

emission levels. Once installed, an effective maintenance regime should be implemented to ensure that noise emission levels do not increase significantly as a result of faults arising from poorly maintained mechanical components.

Turbines can be designed or retrofitted to minimize mechanical noise. This may include special finishing of gear teeth, using low speed cooling fans, mounting components in the nacelle instead of at ground level, adding baffles / dampers and acoustic insulation to the nacelle, using vibration isolators and soft mounts for major components, and designing the turbine to prevent noise from being transmitted into the overall structure.

As mentioned previously the character and to some extent the intensity of noise emission can be changed by switching from downwind to upwind rotor configuration. Additionally, management of rotor speed, pitch and direction can also be used to control noise emission; although these methods can reduce the energy generating capacity of a scheme.

In some cases, especially with older turbine designs, aerodynamic noise has been reduced by remedially treating the tips of the blades.

Any damage to blades, such as holes or cracks, has the potential to increase noise levels and generate tones and such damage should be repaired.

It may also be practical to use Noise Reduction Management Systems to manage noise emission and the effects of AM which may occur under particular meteorological conditions, for example by ceasing or limiting the operation of individual turbines under specific wind conditions. However, these methods all have potentially adverse consequences for the electricity generating capacity of a scheme.

3.9 Noise and Health

The World Health Organisation (WHO) defines health "*as a state of complete physical, mental and social well-being and not merely the absence of infirmity*". The WHO Community Noise document[28], which is the precursor to the WHO Community Noise Guidelines[29], identifies a number of health effects such as: interference with communication; noise-induced hearing loss; sleep disturbance effects; cardiovascular and psycho-physical effects; performance reduction effects; annoyance responses; and effects on social behaviour.

More recently, two detailed reviews of noise and health were published in the UK in 2009 i.e.

- Health Protection Agency - Environmental Noise and Health in the UK (http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1246433634856 - last viewed 8th March 2011)

[28] *Guidelines for Community Noise - Stockholm University and Karolinska Institute, Berglund and Lindvall, 1995*
[29] *WHO Guidelines for Community Noise, London, 1999*

- Defra - Estimating Dose-Response Relationships between Noise Exposure and Human Health in the UK (http://www.defra.gov.uk/environment/quality/noise/igcb/publications/healthreport.htm - last viewed 8th March 2011)

These reports, whilst concluding that insufficient evidence is available to establish robust dose-response curves, suggest that there are links between noise and impacts on health in the form of cardiovascular effects, sleep disturbance, hypertension and children's cognitive development.

Health problems such as persistent sleep disturbance can be classed as "*injurious to health*" and therefore can fall under both the prejudicial to health limb of Statutory Nuisance, as well as the nuisance limb i.e. unreasonably materially interfering with use of a bedroom. However, the modern view in regard to the development of the legal principles of Statutory Nuisance is that they continue to be strongly influenced by the original Victorian sanitary concepts from the 1840's that led to the first Statutory Nuisance legislation[30], and which have been repeated in subsequent legislation. For example, in describing the term "prejudicial to health" the Court of Appeal has commented that:

"*The important point to note from the legislative history is that the expression, which now falls to be construed in section 79 of the 1990 Act, has been repeatedly used by Parliament in the context of what have been characterised as "sanitary statutes"*[31].

The above comment suggests that notions of wellbeing and quality of life which are included in many modern concepts and definitions of health may not be sufficiently robust in their links to the issues that triggered the "*sanitary statutes*" to enable them to be enforced under the prejudicial to health limb of Statutory Nuisance. However, as noted in the discussion of above, the nuisance limb of Statutory Nuisance, whilst strongly influenced by the concepts of civil nuisance, requires that there also needs to be a link to health, in so far that at least personal comfort is being unreasonably materially affected. This suggests that some of the health concepts associated with wellbeing and quality of life that may be difficult to link to the sanitary concepts behind the legislation, may be better tackled as impacts on personal comfort using the nuisance limb of Statutory Nuisance, rather than the prejudicial to health limb[32].

Even though the effects of noise are strongest for quality of life impacts e.g. annoyance, the potential impact of noise upon public health should not be underestimated. Depending on the level of exposure, noise can affect people's quality of life and social wellbeing and can cause people to complain of headaches, stress, depression, mood swings etc. Noise can also cause social conflict and cause people to move home or to avoid certain rooms or outdoor amenity spaces such as the gardens of their dwellings. People can also report going to their GPs, drinking alcohol, and taking headache tablets or

[30] *Nuisances Removal and Disease Prevention Acts 1848 and 1849*
[31] *R v Bristol CC, ex p Everett [1999] 2 All ER 193; Env LR 587.*
[32] *NB: An abatement notice only has to state that Statutory Nuisance is occurring and/or recur; it doesn't have to identify which limb or limbs apply. Although it is likely to be required if the notice is enforced – Lowe & Watson Vs South Somerset DC. [1998] Env LR 143*

anti-depressants because of the noise. In vulnerable groups noise can also exacerbate mental health disordersThe most observed reaction to environmental noise is annoyance. Dose response relationships have been derived for a number of sources of environmental noise. These dose response relationships are often presented as smooth curves showing a steady increase in effect with noise dose. However, it is important to appreciate that human response is often only weakly correlated with noise exposure variables and that dose response relationships are poor predictors of average community response and that dose response relationships cannot be used to predict the response of individuals.

Much of the variance in noise response between individuals can be explained by differences in sensitivity, situational, attitudinal and other socio-psychological factors. The WHO Community Noise document describes annoyance as a feeling of displeasure evoked by a noise. It also goes onto explain that:

"*The annoyance rating capacity of a noise depends upon many of its physical characteristics including its intensity, spectral characteristics, and variations of these with time. However, annoyance reactions are sensitive to non-acoustic factors of a social, psychological, or economic nature, and there are considerable differences in individual reactions to the same noise exposure*"

This short extract from the WHO Community Noise document helps to explain some of the complexities associated with complaints about wind turbine noise. This chapter explains that wind turbine noise contains complex characteristics and features which should be taken into account in assessing the noise. In addition, there are complex attitudinal and behavioural issues to consider.

Guidelines on noise and health, for example the WHO Guidelines for Community Noise and Night Noise Guidelines[33], do not determine whether noise from a wind farm is actionable as a Statutory Nuisance. This is because these guidelines are typically set at noise levels at which it is possible to detect an effect, but this effect may not become significant until higher noise levels are attained. Also they are normally aimed at protecting the whole population including the most vulnerable and sensitive; whereas, Statutory Nuisance only protects those who are ordinarily sensitive[34]. However, the qualifying detail of the WHO guidelines is important, and they can still provide useful advice, for example:

- The WHO Community Noise Guidelines state that they apply to steady and constant sources of noise, and imply that more stringent guidelines may apply to non-steady or intermittent, but persistent, sources of noise.
- The WHO Community Noise Guidelines recommends special attention should also be given to noise sources in an environment with a low background noise level. Therefore where noise from a specific source exceeds the WHO guidelines in low background noise level environments this can be likely to provoke adverse reactions by those who are normally sensitive to noise as well as those who may be more than normally sensitive.

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[33] *Night noise guidelines for Europe (Copenhagen, WHO Regional Office for Europe, 2009 (*http://www.euro.who.int/en/what-we-do/health-topics/environmental-health/noise/publications/2009/night-noise-guidelines-for-europe *) last viewed 8th March 2011) supplements the Guidelines for community noise (Geneva, World Health Organization, 1999 (http://www.who.int/docstore/peh/noise/guidelines2.html - last viewed 8th March 2011)*

[34] *Cunningham Vs Birmingham City Council (1997) 96 LGR 231, 30 HLR 158, [1998] Env LR 1.*

3.10 Wind Turbine Syndrome (WTS) & Vibro-acoustic Disease (VAD)

Some campaign groups and activists have raised the issue of a "wind turbine syndrome" and "vibro-acoustic disease" in regard to wind farm schemes in the UK.

These alleged health effects are largely rebutted in a review by the American Wind Energy Association and the Canadian Wind Energy Association[35] which highlights the poor science and weak methodologies used by the researchers making claims in regard to these effects., although it must be borne in mind that the AWAEA review was not a systematic literature or robust epidemiological study; and that it recognised that noise can have both direct and indirect effects on health

Additionally; the National Health Service has commented on the study alleging WTS as follows:

"*No firm conclusions can be drawn from this study as the design was weak and included only 38 people. Participants were asked about their symptoms before they were exposed to wind turbines to provide a control for their symptoms after exposure. This was not a sufficient control as many of the participants were reportedly already convinced that wind turbines caused their symptoms and were actively trying to move out of their homes or had already moved."*[36]

This report considers that the evidence currently put forward for WTF and VAD in regard to wind turbines is not sufficiently robust to support its use in regard to Statutory Nuisance. Instead this study advises that some of the direct and indirect health effects of noise from many sources are already well established and that knowledge in these areas continues to grow. The current evidence base of the health effects of noise in general is significantly better established and more widely accepted and reported than for WTF and VAD specifically in regard to wind turbines; and attempting to bring a case based on such unproven hypotheses as WTF and VAD is considered unlikely to succeed.

3.11 Dose Response

One of the strengths of common law and Statutory Nuisance which allows these concepts to be adapted to a wide range of circumstances and potential problems; is that legislation and case law establishes there are no fixed standards of comfort applicable to all circumstances[37]; as neither case law nor legislation sets specific noise level thresholds for Statutory Nuisance. The wide range of individual responses to noise and the influence of non-acoustic factors on these responses meant that to try to set fixed standards or noise level based thresholds for Statutory Nuisance would undoubtedly disappoint many noise complainants and potentially unduly penalise numerous legitimate noise makers. This means that dose response relationships are not determinant of Statutory Nuisance.

However, dose response relationships can be useful in providing data linked to the impacts of wind farm noise, albeit there are uncertainties regarding the degree to which the data can be relied upon; which can

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[35] *See Wind Turbine Sound and Health Effects An Expert Panel Review:*
at http://www.awea.org/_cs_upload/learnabout/publications/5728_1.pdf (last viewed 8th March 2011)
[36] http://www.nhs.uk/news/2009/08August/Pages/Arewindfarmsahealthrisk.aspx (last viewed 8th March 2011.
[37] *For example: Sturges vs Bridgeman (187)11 Ch D 852 : 48 LJ Ch 785 ; 41 LT 219; 43 JP 716; 28 WR 200 CA*

allow wind farm noise to be weighed more effectively with and against the other factors used in deciding on Statutory Nuisance e.g. the nature and character of the locality, timing, duration and frequency of occurrence of the noise etc.

Unfortunately, relatively few studies have investigated human response to wind turbine noise, and those that have been undertaken have produced varying results and highlight how, as with most noise sources, non-acoustic factors can significantly influence annoyance responses.

No dose response relationship studies have been carried out in the UK and a review of literature shows those that are available are mainly from work carried out in Scandinavia, Netherlands and Germany. Notwithstanding methodological and analytical issues; differences in societal, environmental and political factors between these countries and Britain may militate against the direct transposition of these dose responses to the UK. However, in order to inform the practical use of this report, there follows a review of published research on the dose response to wind farm noise.

A substantial review of wind farm noise dose response was produced in 2003 by the Swedish Environmental Protection Agency[38], which looked at results of work done in the early 1990's. The turbines studied 20 years ago may not be typical of those currently operating in the UK, but extracts from the study are reproduced and summarised below as a starting point in this review of wind turbine noise dose response.

"*A major study" by Wolsink et al[39], partly funded by the European Community, was performed in Denmark, the Netherlands and Germany in the beginning of the 1990's. The study explored the correlation between noise exposure from wind turbines (dose) and the noise annoyance among the residents (response), as well as other variables of importance for annoyance. Sixteen sites in the three countries where residents were exposed to noise levels above 35 dBA[40] were selected. The sites comprised a total of 134 turbines: 86 (across 4 sites) in the Netherlands, 30 (across 3 sites) in Germany and 18 (across 9 sites) in Denmark. Most of the turbines were small. Only 20 of them had a power rating of 500 kW or above, all the rest were of 300 kW or less. The results presented were based on a total of 574 interviews: 159 in the Netherlands, 216 in Germany and 199 in Denmark. The full response rate is not known. A questionnaire including questions on noise (annoyance, perceived loudness and interference), attitude[41] to wind power, residential quality and stress were used for the interviews. Sound pressure levels were measured on sites, but how these measurements were made is not clear.*

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[38] *Eja Pedersen, Högskolan i Halmstad, Swedish EPA Report 5308, August 2003: Noise annoyance from wind turbines – a review*

[39] *Wolsink M, Sprengers M, Keuper A, Pedersen TA, Westra C A; Annoyance from Wind Turbine Farms on 16 sites in three countries. Proceedings of European Wind Energy Conference 1993, 8-12 March, Lübeck, Travermünde, 273-276;*

[40] *The relevant noise index is not clear from the text of the Swedish EPA review, but given that all three Countries in the Wolsink et al paper recommend use of the $L_{Aeq,T}$ to predict propagation of noise from wind farms it is assumed that this is the intended index in the Swedish EPA report.*

[41] *Guski R, Conceptual. Methodological, an Dose – response problems related to annoyance and disturbance, Inter-Noise 97, pg 1077-1082* - at pg 1077 discusses the use of the term attitude in the context of noise research as follows - *"Most psychologists consider an attitude to be a consistent set of cognitions about a certain topic, and all cognitions share the property of evaluation i.e. they contain a definitive position on the continuous scale of good to bad. Even if we don't have personal knowledge of a topic, we mostly have at attitude about it, sometimes derived from socio-cultural traditions, sometimes by mere associations with the name of the topic."*

And

"*Only a weak correlation between sound pressure level and noise annoyance caused by wind turbines could be found (Kendall's coefficient for correlating rank order variables t=0.09; p<0.05). In addition the actual level of annoyance among the large majority of the subjects was low, the proportion annoyed by noise from wind turbines was 6.4% (n=37).*"

It should be noted that the distribution of the interviews did not match the distribution of the turbines e.g. there were more interviews on the 18 Danish turbines than the 86 Dutch turbines. The results are therefore biased to the 48 Danish/German turbines across 13 sites studied and it is not known how closely they match the 86 Dutch turbines across 4 sites, or to what degree that may reflect current UK turbines and site distributions.

Scrutiny of the original Wolsink et al (1993) study reveals that they conclude that:

1. The proportion of persons indicating annoyance is low at only 6.5% of the survey sample;
2. The degree of annoyance is hardly related to noise level;
3. *"The fact that someone was complaining was mainly determined by the personality of the individual*.";
4. "*The conclusions must not be mis-understood. The fact that sound level is not predicting annoyance does not mean that people are not really annoyed when they are reporting it*."

Importantly, the Wolsink et al (1993) study sounds a note of caution regarding interpretation of its results as "*There are a number of methodological problems involved in the project*" such as:

1. Some of the meaning and validity of the social survey questionnaires could have been "lost in translation" as the same questionnaires were used in each country and "*Translating questionnaires without loss of information is extremely difficult, and interview effects may be different between countries. It may result in incompatibilities between data*." This is particularly important in terms of the different linguistic and cultural meanings between countries[42].of the term annoyance
2. There are analytical problems due to "*extremely skewed data".*
3. Whilst *"The prediction that somebody is not annoyed, irrespective of any other effect, is in most cases already the right prediction. Moreover caution must be taken in order not to ascribe possible effects to outliers, which would make the conclusions not very robust."*

Another more recent (2007) field study has been carried out in Sweden[43] (referred to hereafter as "the Swedish study"). This study consisted of multiple phases, including cross-sectional social surveys to

[42] *Guski R, Conceptual. Methodological, an Dose – response problems related to annoyance and disturbance, Inter-Noise 97, pg 1077-1082* - at pg 1077 highlights issues of the different meaning of the term annoyance across different languages and cultures

[43] *E. Pedersen, Human Response to Wind Farm Noise – Perception Annoyance and Moderating Factors, Occupational and Environmental Medicine, Dept of Public Health and Community Medicine, Institute of Medicine, The Sahlgrenska Academy, Göteborg, Sweden 2007*.

derive a dose-response relationship. Subjective responses were obtained from 1,288 respondents (n = 513 in the phase I study and n = 765 in the phase III study). The first survey was carried out in an area of flat terrain in a mainly quiet rural area whereas the later survey was carried out in areas with different types of terrain (flat or complex) and different degrees of urbanisation.

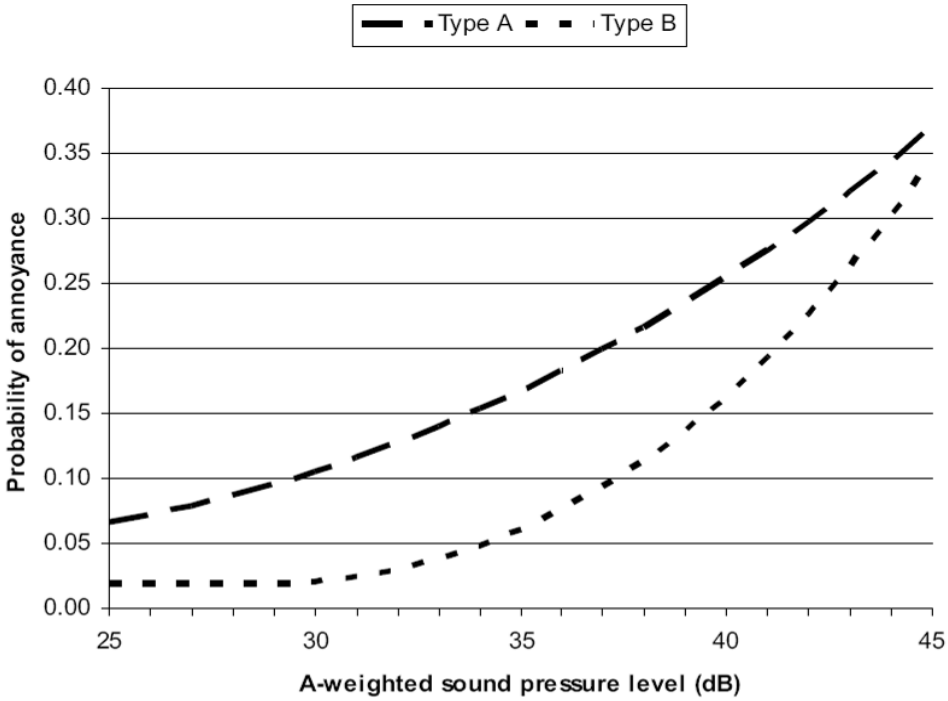
Overall this study considered 12 areas, with either flat or complex topography; and which could be classified as either rural (quiet) or sub-urban (not as quiet); however no specific data on baseline noise levels is provided. Overall the study found a greater probability of the perception of wind turbine noise in quieter rural areas compared to noisier sub-urban locations; and a greater annoyance response rate in quieter compared to noisier locations i.e. more annoyance per wind turbine decibel in rural locations compared to sub-urban locations. The study also postulates the hypothesis that the anthropogenic character of the wind farm noise clashes with the "*natural*" soundscape in the quieter rural areas; provoking a stronger adverse reaction than in sub-urban locations where the soundscape contains a higher proportion of non-natural noises.

The study also considered the impact of visual factors by comparing responses from respondents who could see wind turbines with those who could not see wind turbines. The study found that "*being negative towards the visual impact of wind turbines on the landscape scenery, rather than wind turbines as such, was strongly associated with annoyance."*

Wind farm noise exposure was not measured in the study instead it was calculated in accordance with the method set out by the Swedish Environmental Protection Agency (e.g. assuming wind speed is 8m/sec at 10 m height). The surveys concentrated on external exposure as it was assumed that the noise was rarely heard indoors.

Dose-response relationships were found both for perception of noise and for noise annoyance in relation to A-weighted sound levels derived in accordance with the Swedish Environmental Protection Agency (2001) Guidelines[44]. Two dose-response relationships were presented: one for rural areas (Type A) and the other for suburban areas (Type B) (Figure 6 below).

[44] *The text in section 4.6 of this report suggests that the reported dose responses are formulated for the $L_{Aeq,T}$ noise index.* Whilst in the UK ETSU-R-97 advises *use of the statistical method (LA90) for the measurement of noise from wind farms, most other countries use the Equivalent Continuous method (LAeq). Additionally most other EU countries have fixed limits, the lowest being Sweden and Ireland (40 dB(A) LAeq,t and the highest being Spain (65 dB(A) LAeq,t – although care should be taken when comparing advice from different countries as noise index, time period and definition of night and day periods can vary substantially.*



Type A (rural location, with low background noise levels), and;

Type B (suburban location with higher background noise levels)

Figure 6 Probability of annoyance with wind turbine noise outdoors. Pedersen, E, Persson Waye, K. (2007) Wind turbine noise, annoyance and self-reported health and well-being in different living environments. Occup. Environ. Med. 64, 480–486.

However, several notes of caution are given in regard to the above study. There is the possibility that due to the difference in topography and population densities, and overall noise exposure between Sweden and the UK that the classification of the areas in terms of terrain and urbanisation may be different. Additionally the survey method required the respondent to actively submit their response to the survey, which means the study could be potentially biased by a higher proportion of those adversely affected being motivated to respond than those who had neutral or positive responses and who might be less motivated to reply. A significant methodological issue is that the assessment was solely based on calculation of wind farm noise rather than measurement or validation of the calculated wind farm noise levels; and ambient noise levels due to other sources were also not established. This introduces various uncertainties as to the subjects real noise exposure, which noise source was triggering any measured annoyance response or what may have been the contribution of noise sources other than wind turbines e.g. road, rail and air traffic, to the annoyance responses reported.

Additionally, there are limitations with the “Swedish study” associated with the calculation method used to establish dose in the study, which mean the predicted noise levels must, therefore, be treated as indicative only. For example it is based upon worst case (downwind) assumptions, and wind shear effects on turbine noise emission were dealt with using a standard logarithmic algorithm that took account of

assumed standard ground surface roughness length only and did not take account the temperature effects on wind shear, which site specific data could have dealt with more efficiently; in addition no account was taken of screening or reflections by other buildings etc.

The uncertainties associated with trying to extrapolate the Swedish study are perhaps highlighted by the difference in response found between the two different social surveys (Figure 7 below). Annoyance in phase I was significantly higher than in the phase III. Pederson suggests that this could be partly explained by masking as the proportion of respondents who noticed wind turbine noise increased with increasing A-weighted SPLs, but a higher proportion of respondents who noticed the sound were found at lower A-weighted SPLs in phase I than in phase III. In phase I, 85% or more reported that they noticed the sound at SPLs greater to or equal to 35 dBA. In phase III, 85% or more noticed the sound at noise levels about 40 dBA. The difference could also be explained by differences in screening or terrain effects, the first survey being carried out in flat rural areas; which may not always be relevant to the type of settlement and terrain found in the UK.

Both phases of the Swedish study indicate that mere audibility of wind turbine noise is not sufficient to provoke annoyance in most of the respondents; as there is a significant difference in the percentage perceiving the wind farm noise and those who are annoyed, with a smaller differential at lower noise levels compared to higher values.

The figures below are from the Swedish study and show the proportion of respondents who noticed and/or were annoyed by wind turbine noise in phases I and III. A-weighted SPLs in 2.5 dB intervals are shownand vertical bars indicate 95% confidence intervals, and n = number of respondents at each interval.

Care should be taken when comparing the two studies as phase III was not intended to replicate phase I, as the studies were in different landscapes with different geographical characteristics, and phase III included questions about evaluation of the environment, feelings invoked by wind turbines and coping strategies that were not asked in phase I. The phases show clear differences in the degree of response, which suggests that the response rate is influenced by location specific factors.

However both phases I and III have in common the general trends that:

- annoyance increases with noise level,
- sleep disturbance was associated with annoyance (although only phase 1 showed an association between noise level and sleep disturbance),
- Descriptors of the turbine noise characteristics including "*swishing", "whistling", pulsating/throbbing" and "resounding"* were highly correlated with noise annoyance in both phase 1 and phase 3.

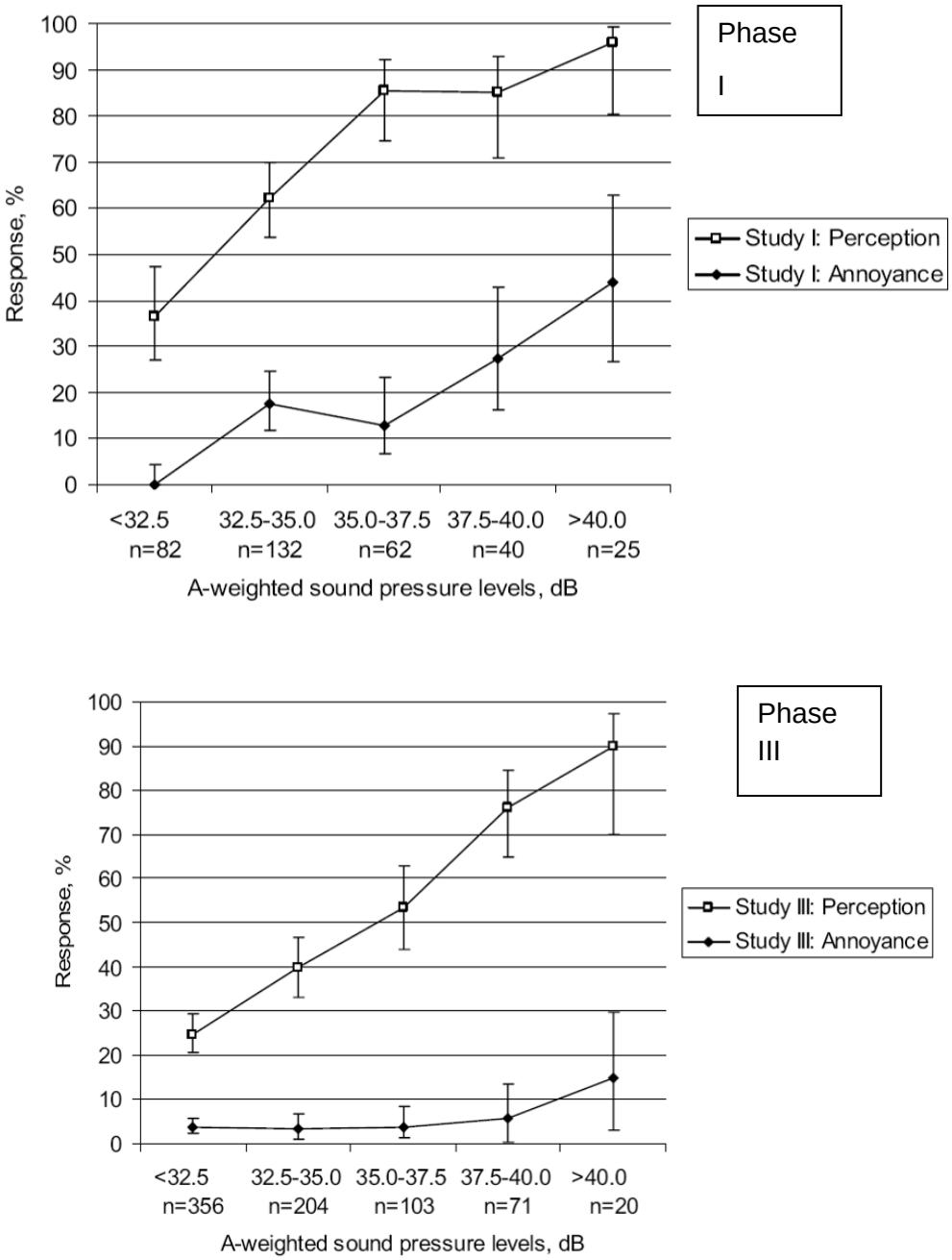


Figure 7 Response to wind turbine noise wind turbine noise. Pedersen, E, Persson Waye, K, (2007) Wind turbine noise, annoyance and self-reported health and well-being in different living environments. Occup. Environ. Med. 64, 480–486.

More recently (2009), work from two surveys in Sweden (n=341, n=754) and one survey in the Netherlands (N=725) has been published[45] on wind farm noise dose response compared to industrial noise, based on a study funded by the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM), which concluded that:

- *At outdoor exposure levels higher than 40 dBA, the expected percentage of annoyed persons indoors due to wind turbine noise is higher than due to industrial noise from stationary sources at the same exposure level.*
- *Besides noise exposure, various individual and situational characteristics were found to influence the level of annoyance.*
- *Having economic benefit from the use of wind turbines, or being able to see one or more wind turbines from within the home are two particularly influential situational factors [with positive and negative effects respectively]*
- *The economic benefit factor is reminiscent of earlier findings that being employed at the noise source (e.g. airport or industry) attenuates the annoyance reported.*
- *Also, visibility from the home (e.g. living room, bedroom) has been reported earlier to affect annoyance from stationary sources.*
- *In addition, noise sensitivity and age had similar effects on [increasing] annoyance to those found in research on annoyance by other noise sources.*

The chart below (taken from the Netherlands study) illustrates that wind turbine noise (measured using L_{den}, dBA) appears to have a higher annoyance rate than industrial noise.

[45] *Janssen, Eisses & Pedersen, Exposure-response relationships for annoyance by wind turbine noise: a comparison with other stationary sources, EURONOISE 2009, Edinburgh.*

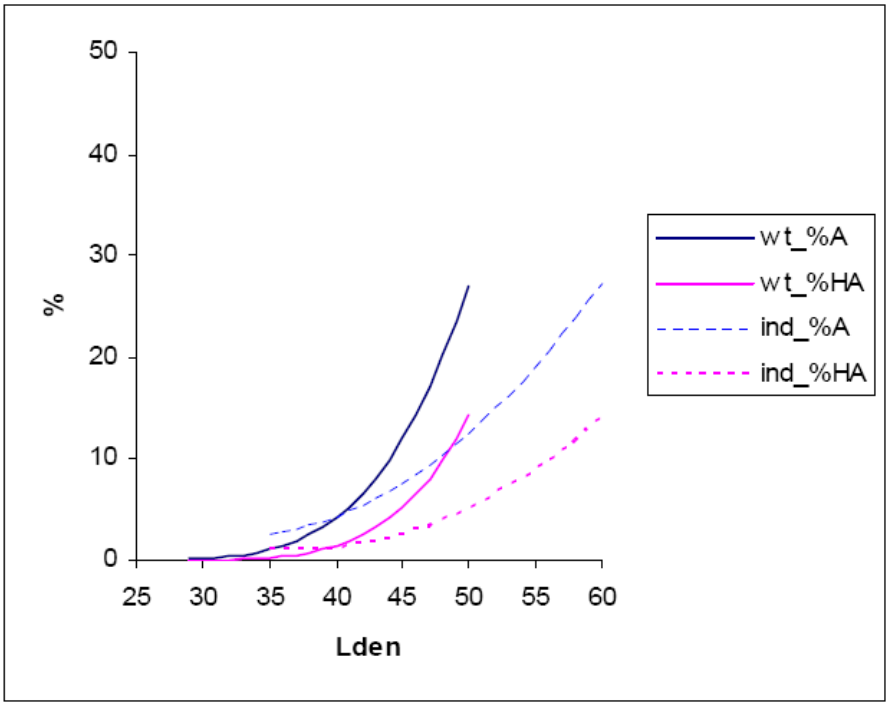


Figure 8 Comparison of the percentage (highly) annoyed persons indoors (*%A indoors* and *%HA indoors*) due to wind turbine noise (wt) and industrial noise (ind). - Janssen, Eisses & Pedersen, Exposure-response relationships for annoyance by wind turbine noise: a comparison with other stationary sources, EURONOISE 2009, Edinburgh.

The study reports that "*the Annual day-evening-night A-weighted equivalent noise level (Lden) was defined in accordance with EU environmental noise guidelines. For each respondent, outdoor A-weighted sound power levels from the nearest wind turbine(s) were determined for a neutral atmosphere at a constant wind velocity of 8 m/s at a height of 10 meters [sic] in the direction towards the respondent, which is the reference wind velocity by convention (e.g. Swedish Environmental Protection Agency, 2001). To these data, a correction of +4.7 dBA was applied, calculated by van den Berg as the mean difference between Lden and the immission level at a wind velocity of 8 m/s. While in principle the correction depends on the wind velocity distribution at a specific location, the type of wind turbine and the hub height, statistical wind velocity data was not available for all study locations. Furthermore, using a variable correction factor for the situation in the Netherlands did not provide a better prediction of annoyance in comparison to Lden calculated with the fixed correction factor*."

Again, the study is based on predictive calculation of wind farm noise, without validation; and there is little if any consideration of existing ambient and background noise levels or other noise sources and their influence on annoyance. Additionally, a significant proportion of the differential in annoyance for wind farm noise and industrial noise could be explained by the approximately 5 dBA correction "*as the mean*

difference between Lden and the [calculated] immission level at a wind velocity of 8 m/s." i.e. correction for wind shear, should such a correction be unwarranted or be higher than required at all the sites in the study at all times of the day.

In 2009 Pedersen and others reported[46] that:

"*The increasing number and size of wind farms call for more data on human response to wind turbine noise, so that a generalized dose-response relationship can be modeled [sic] and possible adverse health effects avoided. This paper reports the results of a 2007 field study in The Netherlands with 725 respondents. A dose-response relationship between calculated A-weighted sound pressure levels and reported perception and annoyance was found. Wind turbine noise was more annoying than transportation noise or industrial noise at comparable levels, possibly due to specific sound properties such as a "swishing" quality, temporal variability, and lack of night time abatement. High turbine visibility enhances negative response, and having wind turbines visible from the dwelling significantly increased the risk of annoyance. Annoyance was strongly correlated with a negative attitude toward the visual impact of wind turbines on the landscape. The study further demonstrates that people who benefit economically from wind turbines have a significantly decreased risk of annoyance, despite exposure to similar sound levels. Response to wind turbine noise was similar to that found in Sweden so the dose-response relationship should be generalizable [sic]*".

The study referred to by Pedersen produced the chart of annoyance versus noise exposure shown in the figure 8 below, which compares the Dutch study results with results from the Swedish study;

[46] *Eja Pedersen, Frits Van Den Berg, Roel Bakker & Jelte Bouma; Response to noise from modern wind farms in The Netherlands; J. Acoust. Soc. Am. 126 _2_, August 2009*

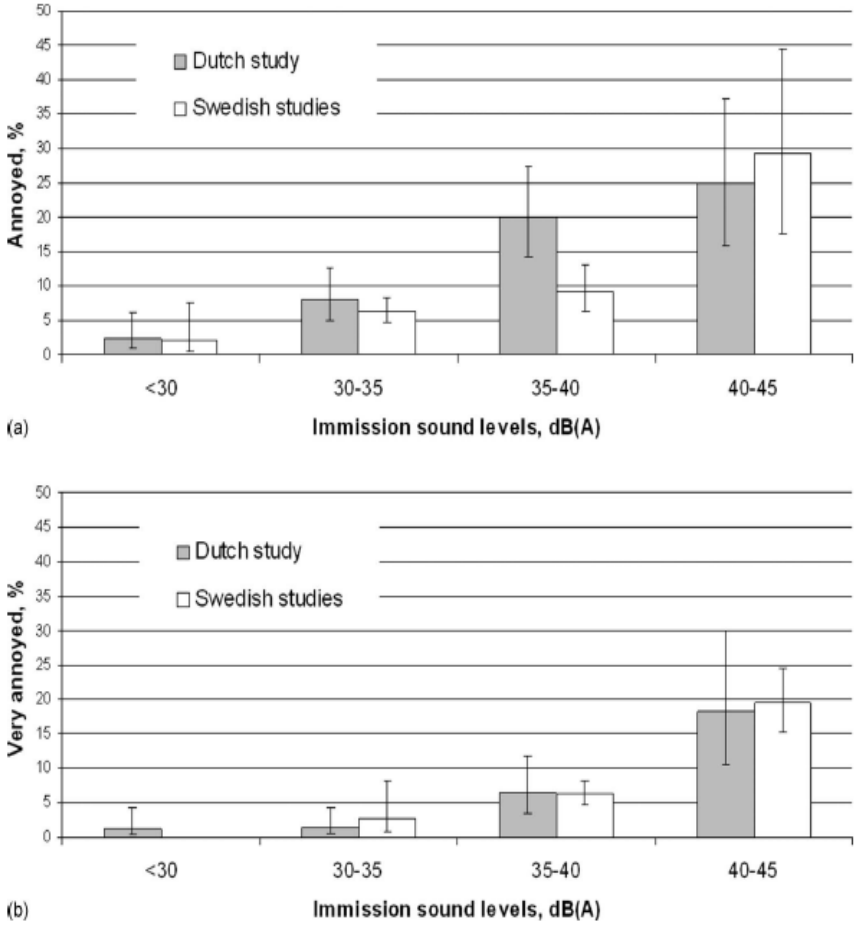


Figure 9 Proportions of respondents annoyed (Fig a) and very annoyed (Fig b) by wind turbine noise outside their dwellings in four sound level intervals[47] in the Dutch study, includes only respondents who did not benefit economically, n=586, and the Swedish studies[48] n=1095, with 95% confidence intervals.

This study concludes the following:

- *"The study confirms that wind turbine sound is easily perceived and;*
- *Compared with sound from other community sources, relatively annoying, and;*
- *Annoyance with wind turbine noise is related to a negative attitude toward the source and to noise Sensitivity, and;*

[47] *Again the study is unclear as to the noise index or the measurement time period, but the propagation model used (ISO 9613) suggests* $L_{Aeq,T}$.

[48] Here the term Swedish studies refers to Phase IV of Pedersen's work described earlier. Phase IV was a synthesis study based on the data sets from phases I and III, and included adjustments for visual angle of view of the turbines and recalculation of the phase I sound levels, as only interval data was available.

- *In that respect it is similar to reactions to noise from other sources, and;*
- *This may be enhanced by the high visibility of the noise source, the swishing quality of the sound, its unpredictable occurrence, and the continuation of the sound at night."*

3.12 The Importance of Acoustic Features

G. P Van den Berg[49] (2005) has investigated the possibility that uneven wind speed across the rotor plane may cause fluctuations in noise emission and has suggested that in stable atmospheric conditions the difference in wind speed between the top and bottom of the rotor of a large turbine is relatively high. This may contribute to a cyclical variation in the noise level, which may be characterised as a '*beating*' – the effect referred to as AM[50]. This type of noise is of interest, as it is likely that a modulated noise will be more annoying than a non-modulated noise at the same sound pressure level. In regard to this point, Frits Van Der Berg (2009) has recently reported that

"*Acoustically this may be due to the diurnal course of the noise and the rapid fluctuation in level related to the rotation, which are not usual features of most transportation and industrial noise sources. It can also be a result of non-acoustic factors such as visual intrusion and the perceived distribution of benefits and adverse effects*."[51].

As wind farm noise typically includes a degree of modulation it will normally be appropriate to include assessment of this factor when investigating complaints. As explained in section 3.4, aerodynamic modulation is not well understood and there are presently no peer reviewed and validated models available through which the occurrence of aerodynamic modulation can be reliably predicted. But this may not be a problem in the context of a statutory nuisance investigation as the law imposes no fixed standard of comfort nor specifies a particular set of acoustic parameters that apply across the board. Consequently, qualitatively describing the nature and character of the turbine noise, and supporting this with measurement methods e.g. short term (50 -125 milli-second) LAeqs, that can quantify and visually articulate information about the modulation; can be useful in supporting a subjective assessment of Statutory Nuisance associated with modulated aerodynamic noise.

In a laboratory study[52] (2002) 25 subjects were exposed to five wind turbine noises of different character, but all at the same noise level of 40 dBA L_{eq}, in order to see if differences between the noises with regard to annoyance could be found. The most annoying noises were predominantly described as "*swishing*", "*lapping*" and "*whistling*". These descriptors could all be regarded as related to the aerodynamic noise and as descriptions of a time varying (modulated) noise with high frequency content.

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49 Van den Berg, G.P. (2005a): "The beat is getting stronger: the effect of atmospheric stability on low frequency modulated sound of wind turbines", Journal of Low Frequency Noise, Vibration And Active Control 24 (1), pp. 1-24; and Van den Berg, G.P. (2006): "Wind induced noise in a screened microphone", Journal of the Acoustical Society of America 119 (2), pp. 824-833 (2006)

[50] AM – Amplitude Modulation of Aerodynamic Noise

51 Frits van den Berg, Why is wind turbine noise noisier than other noise? EURONOISE, Edinburgh 2009.

[52] Persson Waye K. and Öhström E. (2002): "Psycho-acoustic characters of relevance for annoyance of wind turbine noise", Journal of Sound and Vibration 250 (1), pp. 65-73

In another laboratory study[53] (2007) 20 subjects were asked to rate recordings of wind turbine noise with different acoustic features, principally tonal components and aerodynamic noise from the rotating blades. The rated tonality of the stimuli did not correlate well with the metric developed for the prominence of tones - ΔLta. However a metric for calculating '*swishing sound*' was developed i.e. fluctuation strength, which is a measure of amplitude and frequency modulation, which was measured in the 350 Hz – 700 Hz band, and correlated well with the ratings on '*swishing sound'* in the sound played to the test subjects. The frequency band between 350 Hz – 700 Hz was chosen because it seemed to be the optimum range for '*swishing sound*' from large modern wind turbines.

The 2007 Salford University study[54] attempted to establish the prevalence of amplitude modulation of aerodynamic noise (AM) of wind turbine noise. Information was gathered from local authorities and personal knowledge of Council staff was used to determine whether AM was likely to be a factor in complaints about wind turbine noise. Local authorities were asked if the noise contained a number of different features, certain of which could be indicative of AM i.e. *"like a train that never gets there", "distant helicopter", "thumping", "thudding", "pulsating", "thumping", "rhythmical beat",* and *"beating"*. The study suggested that aerodynamic modulation may have been a factor in 4 of the 27 sites associated with complaints included in the survey and a possible factor in complaints at a further 8 sites.

However, the Salford University study's categorisation of AM and the subsequent findings appear to be at odds with other studies which suggest that swishing and other similar descriptors could be associated with AM and that such features are widely prevalent. However, this may simply be a question of semantics as the report by Salford University suggested that swishing type features could be associated with blade resonance not amplitude modulation of aerodynamic noise. In any event the analysis of the complaint information suggests that a significant proportion of the cases may contain acoustic features that could attract attention and may therefore enhance annoyance. For example if the 4 sites in the Salford study where the study suggests AM was a factor are added to the 8 where AM was a possible issue this gives a total of 12 sites with probable or possible AM. In the context of the 27 sites associated with complaints (which are more relevant to this report than the entire 133 sites in the full study) this suggests AM may have been a factor at between 15% to 44% of the sites associated with complaints. Some commentators have distinguished the 4 cases where the Salford study suggests AM was a factor as probably being "*excess AM*" of greater modulation over and above the normal "*swish*" AM typically expected for a wind turbine. The Swedish field study referred to earlier found that the sound characteristics of wind turbine noise, generated by the rotation of the blades, were found to be especially annoying. Noise from rotor blades was noticed more than noise from machinery (see Figure 10). Whilst descriptors of sound characteristics relating to sound from the rotor blades were highly correlated with

[53] *Legarth SV, Auralisation and assessment of annoyance from wind turbines; 2nd international meeting on wind turbine noise, Lyon, France 2007.*

[54] *A. Moorhouse, M. Hayes, S. von Hünerbein, B. Piper, M. Adams, "Research into Aerodynamic Modulation of Wind Turbine Noise", URN 07/1235, University of Salford and Department for Business, Enterprise & Regulatory Reform, UK (2007).*

noise annoyance. Sound characteristics describing the aerodynamic modulation were appraised as the most annoying (swishing, whistling and pulsating/throbbing).

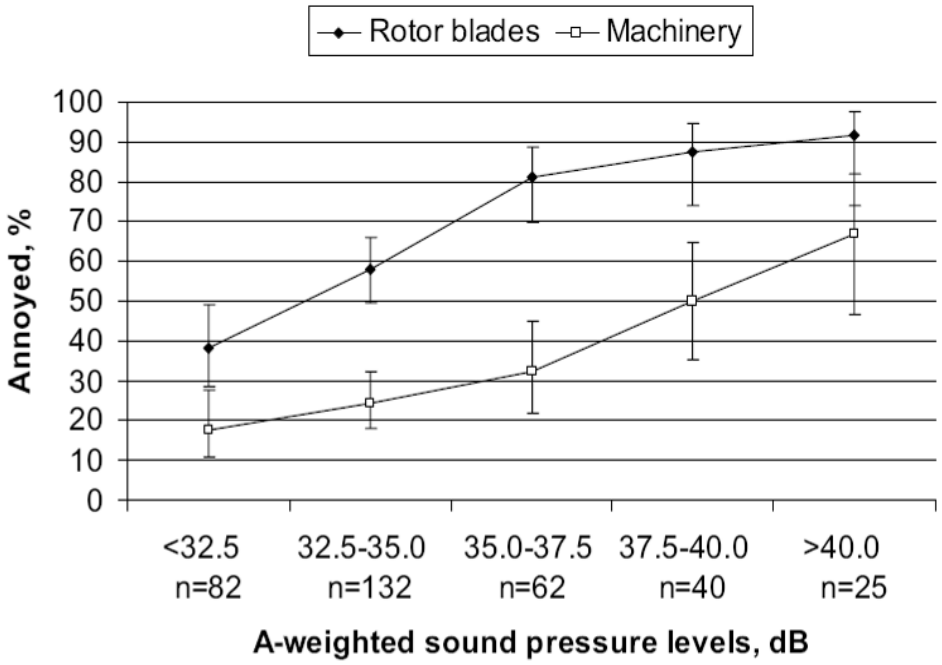

Figure 10: Annoyance of wind turbine noise and mechanical sources. Pedersen, 2007. Proportion of respondents annoyed by sound from rotor blades and machinery, respectively, outside their dwelling in Study 1, in relation to SPLs in 2.5 dB intervals

A case study carried out in the Netherlands (G. P Van den Berg, 2004) showed that aerodynamic modulation can be stronger under certain meteorological conditions and that periodic swishes are louder in a stable atmosphere associated with night time than in daytime, and residents can use words like "*clapping, beating or thumping*" to describe the character or the sound. In the case of the Rhede wind park, the beating could be heard clearly at distances up to 1 km, and at night the beat of the noise could be used to determine the rotational speed of the turbine. When the atmosphere becomes more stable, which is usual during the night when there is a partial clear sky and a light to moderate wind (at ground level), there is an important change in the wind profile affecting the performance of modern, tall wind turbines. The airflow around the blade then changes to less than optimal, resulting in added induced turbulence. It was suggested that this effect is strongest when the blades pass the tower, causing short lasting higher sound levels at the rate of the blade passing frequency. The synchronisation of these

pulses from multiple turbines can give rises to additive effects at a distance and the repetitive pulses may be expected to cause added annoyance.

However, it has been suggested (SIROCCO) that the effect of the passage of the blade past the tower is relatively small in comparison to that attributable to the downward sweep of the blade as it approaches the observer, according to the data on which the study was based (Oerlemans and Lopez, 2005) indicating that the latter can give rise to a modulation of some 12 dB in certain one-third octave bands.

A study undertaken for the Department of Trade and Industry (Hayes Mackenzie, 2006)[55], which focussed on low frequency noise arising from three wind farms within the United Kingdom, indicated that the level of modulation from peak to trough was 2-5 dBA when measured externally and 4-6 dBA when measured internally. The depth of the modulation within individual one-third octave bands was found to be up to 10 dB. The report therefore concludes that "*some wind farms clearly result in modulation at night which is greater than that assumed within the ETSU-R-97 guidelines*." i.e. excess AM. The report then goes on to suggest that in conditions of high aerodynamic modulation it may therefore be appropriate for a correction for the character of the noise to be applied.

The Salford University AM study[56] reports in section 5.6 in regard to the 4 sites where AM was identified as a factor in complaints that they found modulation in noise levels as follows :

"*Measurements of the internal noise levels during these periods of wind farm operation indicate that A-weighted noise levels are subject to amplitude modulation levels of between 3 – 5 dB(A). Analysis of these periods using third octave band analysis indicates that between 200 – 800 Hz, noise levels in specific frequency bands may change between 8 – 10 dB. External measurements indicate that, for external A-weighted changes in level of 3 – 4 dB(A), third octave band levels may change by between 7 – 9 dB. Measurements reported for Wind Farm D (Table 1) have indicated that third octave band levels when complaints were received before the implementation of wind turbine control features, indicated level changes of 12–15dB. (All the above figures are ranges from peak to trough).*"

Useful information on which frequency bands it might be helpful to concentrate investigation of possible AM is provided by the DTI report into low frequency noise and wind turbines (Hayes Mackenzie, 2006), which indicates that "*the dominant audible noise associated with wind turbine operation is acoustic energy within the 250-800 Hz frequency region which originates from the aerodynamic modulation of the wind turbine noise*.". Whilst the Salford AM study advises that "*The finding that this modulation is concentrated between the frequency bands of 200 – 800 Hz is significant in that this is generally generated by the trailing edge of a wind turbine blade. This has been identified as one of the main*

[55] *Hayes Mckenzie, "The measurement of low frequency noise at three UK wind farms", Hayes Mckenzie Partnership Ltd, report to the Department of Trade and Industry (2006) – see* http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/energy/sources/renewables/explained/wind/onshore-offshore/page31267.html *(last viewed* 8th March 2011*)*

[56] *A. Moorhouse, M. Hayes, S. von Hünerbein, B. Piper, M. Adams, "Research into Aerodynamic Modulation of Wind Turbine Noise", URN 07/1235, University of Salford and Department for Business, Enterprise & Regulatory Reform, UK (2007).*

sources of aerodynamic noise associated with the operation of wind turbines (Oerlemans and Lopez, 2005)."

3.13 Individual and Other Situational Factors

Human response, and hence complaints, can be strongly influenced by individual and situational factors and an EHO's assessment of complaints of noise nuisance should not be influenced by such factors; as the investigation of Statutory Nuisance complaints relates to assessing potential impact on a notional average person (often referred to as "*the man on the Clapham omnibus*"[57]) whose response to a noise is deemed to be typical of the population as a whole rather than influenced by personal or situational factors.

It is known from other studies of general environmental noise that visual impact and other variables are important and in certain circumstances it may be found to be more relevant than noise level in influencing response. For example, work[58] on the influence of non-acoustic factors on the human response to noise has concluded that.

"*It is well known that annoyance reactions of residents exposed to environmental noise are determined partly by acoustical features of the environment, partly by features of the residents. At best, about one third of the variance of annoyance reactions can be "explained" by the variance of acoustical features, another third by the variance of personal or social variables."*

and

"*Noise annoyance is considered to be the (long-term) negative evaluation of living conditions with respect to noise. This evaluation is not simply dependent on past disturbances, but on attitudes and expectations, too. The personal factors influencing the evaluation are: Sensitivity to noise, fear of harm connected with the source, personal evaluation of the source, and coping capacity with respect to noise. The social factors are: General (social) evaluation of the source, trust or misfeasance with source authorities, history of noise exposure, and expectations of residents*."

Additionally, other researchers[59] have concluded that the following can influence individual factors can influence the response to environmental noise:

- *"The awareness of non-noise problems may increase annoyance,*
- *Fear of the noise source can increase annoyance,*

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57 "*The man on the Clapham omnibus"* is an ordinary, reasonable person, a theoretical person against whom a defendant's alleged tortuous (wrong) conduct might be judged in a civil action for negligence or nuisance. This is the standard which might be expected by "*the man on the Clapham omnibus*" mentioned by Greer LJ in *Hall v. Brooklands Auto-Racing Club* (1933) 1 KB 205.

58 Guski R. Personal and social variables as co-determinants of noise annoyance. Noise Health 1999;1:45-56

59 Fields JM (1990) A quantitative summary of non-acoustical variables' effects on reaction to environmental noise. Noise-Con 90, University of Texas, Austin. P 303-308

- *The belief that the noise source is important can decrease annoyance,*
- *The belief that the noise could be prevented can increase annoyance."*

The above suggests that it may be the case where wind turbines are regarded as an unwelcome, dangerous or avoidable intrusion that the response of some people to the noise may be more than in circumstances where such factors do not apply. The outlook of study respondents towards the source, is known from other community noise studies to influence annoyance, and was found to be associated with noise annoyance in the Swedish study referred to above. 13% and 8 % of the respondents in the phase I and phase III surveys respectively had negative or very negative attitudes towards wind turbines. Having such negative opinions towards wind turbines was not associated with the A-weighted noise level but was associated with annoyance due to wind turbine noise. The Swedish study states that "*Of the respondents in phase I 40% were negative or very negative about the impact of turbines on the landscape scenery*" and "*sixteen % of the respondents in phase III were negative or very negative to this impact*. There were no differences between residents living in flat areas and those in complex terrains. Although in phase I residents in rural areas were slightly more negative than those is suburban areas. Wind turbines were judged to be environmentally friendly by most of the respondents, followed by positive evaluation of the utility ("*necessary*" and "*efficient*") and a negative evaluation of aesthetic appearance ("*ugly*" and "*unnatural*"). However, the correlation coefficients between the study subject's general point of view towards wind turbines and noise annoyance in these studies were lower than those found in other community noise studies. The general outlook towards wind turbines was of less importance than was visual opinion.

The Swedish study investigated the relationship between noise annoyance and the visibility of the turbines and people's attitudes about the visual appearance of the turbines. Visibility was investigated using a measure of the vertical visual angle; defined as the angle between the horizontal plane and an imaginary line from the dwelling of a respondent to the hub of the nearest wind turbine, expressed in degrees. Visual attitude was measured in terms of the respondents' attitude towards the impact of the wind turbines on the landscape scenery, using bipolar descriptions "*beautiful*"- "*ugly*" and "*natural*"- "*unnatural*". Visual attitude had a large influence on noise annoyance among respondents living on flat terrain, but no statistically significant influence among respondents living on complex terrain. The main individual factor that influenced response to wind turbine noise was attitude towards the visual aspects of the turbines. Pederson suggests that negatively appraising the impact of the wind turbines on the landscape scenery was highly associated with noise annoyance. The risk of noise annoyance increased when the wind turbines were visible i.e. residents who could see at least one turbine from their home were more negative of the impact of wind turbines on the landscape.

Adverse feelings aroused by the wind turbine noise were influenced by feelings of lacking control, being subjected to injustice, lacking influence, and not being believed. Appraising an exposure to noise as an

unfair social situation has, in experimental studies, been shown to increase the risk of noise annoyance[60] Surprisingly noise sensitivity was only correlated to response to wind turbine noise to a low degree.

3.14 Type of Area and Relevance of Background Noise

An increased risk of perception of wind turbine noise was found in the Swedish field study in those areas that were rated as quiet compared with non-quiet areas. Also, the risk of annoyance was increased in quiet areas, indicating that the contrast between the wind turbine noise and the background noise could make the turbine noise more easily detectable and subsequently more annoying; although confounding factors such as expectation of peace and quiet, effects of visual impact and attitude to wind turbines could have an influence on annoyance response, and be more marked in quiet compared with non-quiet areas.

The higher risks of perception and annoyance in quiet areas were reflected in the differences found between rural and suburban areas in the Swedish study. The results showed higher risks of both perception and annoyance in rural landscapes compared with suburban areas. The rural areas presumably comprised background sounds of lower levels than those found in a suburban area. Pederson argues that the character of the sound is also different and that background sound of a rural area mainly contains natural sounds leading to large contrasts between the wind turbine noise and the background sound. A constant swishing noise could in the context of such a soundscape be experienced as intrusive, and may also be incongruent with sounds normally expected in such a surrounding.

However, as noted earlier, there are limitations associated with the calculation method used to establish dose in the Swedish study and the study was not sufficiently powerful by itself to safely conclude that response is significantly influenced by the contrast or the difference between the background noise and the specific wind turbine noise.

The influence of background noise was investigated by Legarth[61] in the laboratory where 20 subjects were asked to rate recordings of wind turbine noises with and without background noise. The results of the listening tests are shown in Figure 11, reproduced from the paper, which are presented alongside the results from other field studies (Pederson, T. Holm, 2007). The study clearly found that by adding natural background noise, the wind turbine sound is masked at low levels and becomes less annoying. The Lden parameter has been used, which is defined in terms of the ‘energy average’ LAeq, t levels during the 12 hour daytime period (0700-1900), 4 hour evening period (1900-2300) and the 8 hour night time period (2300-0700), with an additional 5dB penalty for the evening period and a 10dB penalty for the night time period.

[60] E Maris, PJM Stallen, H Steensma, R Vermunt, INTER-NOISE 2006 3-6 DECEMBER 2006 HONOLULU, HAWAII, USA - (Un)Sound management -Three laboratory experiments on the effects of social non-acoustical determinants of noise annoyance. And; E. Maris, PJM Stallen, H. Steensma, and R. Vermunt - Evaluating noise in social context: the effect of procedural unfairness on noise annoyance judgments. J Acoust Soc Am. 2007 Dec;122(6):3483-94.

[61] Legarth SV, Auralisation and assessment of annoyance from wind turbines; 2nd international meeting on wind turbine noise ,Lyon, France 2007.

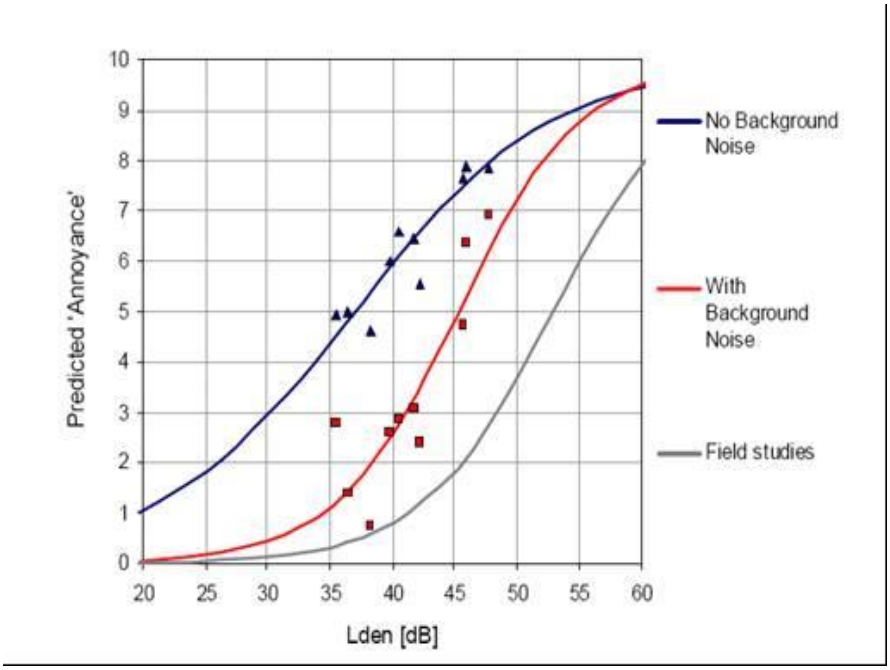

Figure 11: Annoyance of wind turbine sounds. Prediction model on annoyance for the 90-second wind turbines sounds with and without natural background noise. Legarth SV, Auralisation and assessment of annoyance from wind turbines; 2nd international meeting on wind turbine noise ,Lyon, France 2007.

As suggested by the work undertaken by GP Van den Berg and by others[62],in situations with high wind shear – lower wind speed near the ground and higher wind speed at turbine hub height – the background noise at ground level may be relatively low, with the higher wind speeds experienced by the turbine blades resulting in higher aerodynamic noise emission from the turbine than expected using the wind speed at heights lower than the hub. The masking provided by the background noise in such circumstances may be reduced. Consequently, it is important that this potential confounding issue is taken into account in planning the investigation of noise complaints.

3.15 Health Effects

Eja Pederson carried out a review of health effects from wind turbine noise in 2003[63]. She found that there is no scientific evidence that noise at levels emitted by wind turbines could cause health problems other than annoyance. However, she suggests that sleep disturbance should be further investigated. As noise from wind turbines can have special characteristics (amplitude / aerodynamic modulation and “, *swishing*” sounds). As with any noise that has temporal and spectral characteristics different from the

[62] *Klug H, A Review of Wind Turbine Noise, First International Meeting on Wind Turbine Noise: Perspectives for Control, Berlin 17th and 18th October 2005*
[63] *Pedersen E. (2003): “Noise annoyance from wind turbines - a review”, Swedish Environmental Protection Agency*

prevailing soundscape it may be detected when near to or even below background noise levels and this may increase the probability of annoyance and sleep disturbance[64] (although other work suggests a significant gap between wind turbine noise being audible and significant annoyance effects – ref footnote 29). Pedersen comments that the combination of different environmental impacts e.g. intrusive sounds, visual disturbance and the inability to avoid the source in the living environment, could lead to a low-level stress-reaction, which should be further studied.

These findings were confirmed in the Swedish study conducted by Pederson. In phase I of the study, the A-weighted sound pressure level was correlated with sleep disturbance; however this result was not replicated in the phase III survey. In the first survey 16% of the respondents exposed to noise levels above 35 dBA stated in an open question that they were disturbed in their sleep by wind turbine noise. Only a few respondents reported impaired health and social well-being and no association between wind turbine noise and health was found.

The absence of strong evidence on the existence of health effects from wind turbine noise should not be taken as proof that such effects do not occur. However, it would appear that the self-reported health effects associated with wind turbine noise are significantly weaker compared with other types of noise, for example the findings reported for domestic noise[65].

Pedersen has updated her work with a recently published paper[66] (2009) and reports that

- Based on data from two Swedish studies and one Dutch study in which self-reported health and well-being were related to calculated wind farm A-weighted sound pressure levels outside the dwelling of each respondent. The main adverse effect was annoyance due to the sound, and the prevalence of noise annoyance increased with increasing sound pressure levels.
- Disturbance of sleep was related to wind turbine noise; the proportion of residents reporting sleep disturbance in one of the Swedish studies due to noise increased significantly at sound levels close to those recommended as the highest acceptable levels in Sweden (Maximum recommended external level for houses, educational establishments, nursing homes/hospitals = 40 dBA $L_{eq,t}$ - Swedish EPA report 78.5 – As amended) while the Dutch study showed this at a higher level (45dBA).
- No other clear associations between sound levels and self reported health symptoms have been found.
- However, a statistically significant association between annoyance and symptoms of stress was found.

[64] *Ditto footnote 57 at page 10 and Kloosterman, H., Land, D., Massolt, J., Muntingh, G., van den Berg, F. (2002): Hohe Mühlen fangen viel Wind - NWU-106 D. Rijksuniversiteit Groningen as cited in footnote 57*

[65] *Stansfeld S., Brown B., Haines M., Cobbing C. (2000) The Development of a 'Standardised Interview to Assess Domestic Noise Complaints and their Effects, Final Report, Department of Psychiatry, St Bartholomew's and the Royal London School of Medicine and Dentistry, Queen Mary and Westfield College.*

[66] *Eja Pedersen, Effects of wind turbine noise on humans, Third International Meeting on Wind Turbine Noise Aalborg Denmark 17 – 19 June 2009*

- The study design does not allow causal conclusions, but the association indicates a possible hindrance of psycho-physiological restitution. Such a hindrance could in the long term lead to adverse health effects not detected here.

None of the above effects are unique to wind turbine noise[67], although it is unclear whether the dose-response for wind turbine noise is the same as for other noise sources; as several of the studies referenced above suggest that wind turbine noise is more disturbing than transportation and industrial noise sources.

3.16 Published Environmental Noise Guidelines

The main potential effects of wind farm noise on people are annoyance, sleep disturbance and factors affecting quality of life. In the absence of reliable dose response relationships specifically for wind turbine noise; assessment criteria and impact rating procedures derived from generic guidelines and standards for analogous sources are often used as a proxy for assessing the effects of noise on people.

The World Health Organisation has published a number of reports concerning the effects of noise, including Environmental Health Criteria 12 – Noise, 1980 and Guidelines for Community Noise, 1999 and the Night Noise Guidelines for Europe 2009. These guidelines and criteria have in some cases been propagated further and adopted in British Standards (notably BS 8233: 1999 – Sound insulation and noise reduction for buildings – Code of Practice and UK planning guidance (Planning Policy Guidance 24 – Planning and Noise).

The 1980 WHO guideline value to avoid *'interference with the restorative process of sleep'* by continuous noise was specified as 35 $L_{Aeq,T}$ as measured in the bedroom, whereas the 1999 recommended guideline value for continuous noise *'if negative effects on sleep are to be avoided'* was specified as 30 $L_{Aeq,T}$. An additional L_{AMax} guideline of 45 dB was advised in the 1999 document to avoid sleep disturbance caused by individual noise events.

For reported annoyance, the 1980 WHO EH Criteria 12 guideline was that:

'*daytime noise levels of less than 50 dBA Leq cause little or no serious annoyance in the community*'… *'Taking into account other factors such as transport needs, ..., daytime noise limits in the region of 55 dBA Leq might be considered as a general environmental health goal for outdoor noise levels in residential area*s'. The 1999 document meanwhile, states that: *'the threshold of annoyance for steady-state, continuous noise is around 50 dB LAeq. Few people are seriously annoyed during the day time at noise levels below around 55 dB LAeq*'.

It should be noted there were differences in the definitions of the different effects of noise considered and the metrics in which the guideline values were specified between the 1980 and 1999 WHO publications e.g. the 1980 guidelines uses different sleep disturbance objective than the 1999 version, and the 1980

[67] *For example, noise annoyance for the same level of transportation noise is greatest for aircraft, less so for road traffic and least for railway noise - Miedema, H. M. E., Vos, H. Exposure response functions for transportation noise. Journal Acoustical Society of America 104, 3432-3445 (1998);*

guidelines assume that a façade with a partial open window typically provides a 10 dBA difference in between external and internal noise levels from an external source; whereas the 1999 guidelines assumes a 15 dBA reduction. Given these differences, it is therefore difficult to compare the two sets of guideline values because of differences in the way the noise and its effects were measured.

It is also important to note that the WHO guideline values are proposed as a contribution to policy development and are not intended as standards in a formal sense. The guidelines can be therefore be regarded as a consensus view of opinion on the lowest noise levels below which the occurrence rates of particular effects can be assumed to be negligible as the "*the guideline values take into consideration the identified health effects and are set, based on the lowest levels of noise that affect health*[68]". However, exceeding the guideline values should not necessarily be considered to imply a significant noise impact, and it may be that significant impacts do not occur until the higher levels of noise exposure are experienced.

Exposition of various noise guidelines and criteria current at the time of its publication was presented in ETSU-R-97, whilst a review of the health effects of noise and its context within the UK has recently been published by Defra[69] and the Health Protection Agency (HPA, 2009)[70].

The 2009 study carried out by Pedersen found that significant annoyance may occur at daytime levels of wind turbine noise well below $L_{Aeq,T}$ 55 dB during the day. She argued that annoyance may be associated with low levels of exposure to wind turbine noise because of their particular features. The WHO Guideline Values are mainly based upon community studies about transportation noise, and the Guideline Values are meant to apply to types of environmental noise that are steady and continuous[71]. Given the uncertainty that exists, it may be premature to discount the possibility that wind turbine noise could cause adverse effects when the wind turbine noise levels are below the WHO guidelines.

In the UK, the impact of a specific noise is often assessed by comparing the rating noise level against the background noise or the prevailing ambient noise level. For example, the BS 4142 noise rating method assesses the likelihood of complaints from noise of an industrial nature, based on the margin by which it exceeds a background noise level with an appropriate correction for the acoustic features present in the noise. However, it should be noted that the rating method is not underpinned by any rigorous scientific research, with the foreword of the standard itself acknowledging that "*The user is reminded that this standard is not based on substantive research but rather on accumulated experience*." This is also the case with its application to wind turbine noise.

ETSU-R-97 – which the relevant planning policy and advice across the UK either recommends should be used to assess and rate noise from wind energy development; or as good practice in doing so, is to a

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[68] WHO Guidelines for Community Noise , Section 4 Guideline Values, sub-section 4.6, 5th paragraph,

[69] *BEL PROJECT REPORT. BEL 2009 - 001. July 2009 see http://www.defra.gov.uk/environment/quality/noise/igcb/documents/project-report.pdf (last viewed 8th March 2011)*

[70] *Environmental Noise and Health in the UK. Health Protection Agency, 2009 see http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1246433634856 - last viewed 8th March 2011)*

[71] *WHO Guidelines for Community Noise 1999 – guideline values section 4.3.1, 2nd paragraph.*

large extent, based upon BS4142, which itself is not an assessment of Statutory Nuisance, although a number of aspects have been adapted to make it applicable to wind turbine noise. The ETSU-R-97 document describes a framework for the assessment of wind farm noise and provides indicative noise levels considered 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 by 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*."[72]

The noise levels advocated are free-field limits external to noise-sensitive properties, which are either set relative to the background noise level or against absolute limits, depending upon the specific circumstances of the site. As acknowledged within the document, compliance with the proposed limits does not necessarily prevent some adverse noise impact it simply aims to provide a "*reasonable degree of protection*". Instead the document seeks to balance the protection of amenity with the broader public interest, which may not be best served through the application of more stringent controls (compliance with which may not be technically feasible or cost prohibitive).

Consequently, in quiet locations with existing noise levels less than the lower limits from ETSU –R -97 of 35 dB $L_{A90,10\ min}$ during the day or 43 dB $L_{A90,10\ min}$ at night; compliance with these lower noise limits can result in significant increases in noise. ETSU- R- 97 limits, however, are derived from precautionary guidelines which provide a high degree of protection. These guidelines were derived from studies of the effects of continuous noise under steady state conditions i.e. studies of the reaction of different individuals exposed to different noise levels; not the reaction of individuals to changing noise levels. This approach therefore considers the impact of the absolute level of the noise and does not take into account how the characteristics of the noise or the change in noise may itself aggravate the noise impact; which is a well established effect, for example for transportation noise[73]. Additionally, the WHO advises that in low noise environments lower noise levels than the guidelines it recommends may be appropriateETSU-R-97 requires that noise from the wind farm should generally be limited to 5 dBA above background levels for both day and night time periods, except where the prevailing background noise levels are low. The $L_{A90,10min}$ descriptor is to be used for both background noise and the specific noise from wind turbines, with the $L_{A90,10min}$ generally accepted as being 2 dBA lower than the $L_{Aeq,10min}$. In low noise environments, a fixed limit of 43 dBA is recommended for night-time, whilst during the daytime an absolute level within the range 35-40 dBA is proposed; the actual value chosen depending upon the number of dwellings affected, the effect of noise limits on the power generation of the development and the duration of the exposure.

[72] ETSU-R-97 Section 6 Noise Limits: Introduction

[73] Griffiths, I.D. and Raw, G.J., 1986. Community and individual responses to changes in traffic noise exposure. Journal of Sound and Vibration, 111(2),209-217.; and, 12. Griffiths, I.D. and Raw, G.J., 1989. Adaptation to changes in traffic noise exposure. Journal of Sound and Vibration, 132(2), 331-336. ;and, Guski R. How to forecast community annoyance in planning noisy facilities. Noise Health 2004;6:59-64

For single turbines or wind farms with very large separation distances between the turbines and the nearest properties, a simplified noise condition is proposed, such that if the noise is limited to 35 dB $L_{A90,10min}$ up to wind speeds of 10 m/s at 10 m height, then this alone may provide sufficient protection of amenity and preclude the need to undertake background noise surveys.

A penalty for tonality is also set out in order to reflect the increased potential for annoyance that arises when such acoustic characteristics are present on site. The proposed method is based upon the Joint Nordic Method. The magnitude of the penalty varies from 0 to 5 dB depending upon the degree of audibility and is assessed through frequency analysis of both the source noise and the masking noise at receiver locations.

Within the ETSU-R-97 document at page 68 there is a discussion of blade swish, which advises that:

"*The modulation or rhythmic swish emitted by wind turbines has been considered by some to have a characteristic that is irregular enough to attract attention. The level and depth of modulation of the blade noise is, to a degree, turbine-dependent and is dependent upon the position of the observer. Some wind turbines emit a greater level of modulation of the blade noise than others. Therefore, although some wind turbines might be considered to have a character that may attract one's attention, others have noise characteristics which are considerably less intrusive and unlikely to attract one's attention and be subject to penalty*.

This modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3 dBA (peak to trough) when measured close to a wind turbine."[74]

A review of noise complaints was carried out as part of the development of the ETSU-R-97 method. However, the ETSU method, like the BS4142 method (as confirmed in the foreword to the standard), at the time of its development represents the consensus of a group of experts in the absence of robust dose response or scientific studies to underpin its development.

Research carried out by Fields[75] has questioned the reliability of rating methods based upon a comparison of a target noise against the general prevailing ambient noise. This study reviewed evidence from 33 social surveys and findings from 22 laboratory studies to investigate the relationship between residents' annoyance with a major noise source and other ambient noise. The study found that residents' reactions to specific environmental noises (target noises) have been found not to be strongly or statistically significantly affected by the presence of other noise sources in residential areas. Fields suggests that:

"*For the most common environmental noise sources there is no empirical support from privately expressed feelings for a substantially less lenient noise policy towards a target noise in a high ambient residential area than in a low ambient residential area.*"

[74] See page 48 above for discussion of the Salford University report whicg found greater levels of modulation at a small number of site.
[75] *Fields J. M., 1998 "Reactions to Environmental Noise in an Ambient Noise Context in Residential Areas" Journal of the Acoustical Society of America 104, p. 2245-2260*

Of course, ambient noise can mask to varying degrees noise from a particular source of noise if the specific noise level is close or below the ambient or background noise levels. Whilst many wind farms are found in comparatively low noise environments, wind turbine noise levels are generally lower than exposure to other sources of environmental noise, such as road traffic noise. Consequently, the effects of masking may be more important than for other sources of environmental noise.

3.17 Complaint Statistics

Statistics about noise complaints from wind farms in the UK were reviewed by Salford University in their study of aerodynamic modulation and also in the preparation of ETSU-R-97. The Salford University study surveyed all local authorities in the UK in whose areas there were wind farms that had attracted formal public complaints about noise. Up to 2006, this was reported as being 27 wind farms out of 133 wind farms operating at the time of the survey, i.e. 20% of the total. The survey's conclusions were that:

- The results showed that 27 of the 133 wind farm sites operational across the UK at the time of the survey had attracted noise complaints at some point.
- An estimated total of 239 formal complaints have been received about UK wind farm sites since 1991, 152 of these complaints were in regard to noise from a single site i.e. data was skewed towards this site.
- The estimated total number of complainants is 81 over the same sixteen year period.

In considering the origin of the noise which had given rise to the complaints, the Salford study found that of the 27 sites from which complaints had been received, 11 of these were directly attributable to mechanical noise. Four cases were believed to have arisen from the effects of AM, whilst in a further 8 cases the influence of the modulation effects was found to be a possible factor[76].

However, caution is advised against placing too much reliance on complaint statistics because:

- Complaints often reflect only a small proportion of the numbers of persons affected.
- Complaint data can be skewed by individuals who complain more often and frequently than others who may be affected.
- Complaints may not be recorded by LAs as due to noise from wind farms or may not go to LAs e.g. the Police, MPs or the operator may be contacted instead.
- Other possible causes of noise complaints include:
    - In sheltered locations the background noise at the property, which normally helps to mask noise from the wind farm, may not increase when conditions are windy at the wind farm; therefore the wind farm noise is more intrusive.

[76] As noted elsewhere in this report the Salford University Study's analysis is contested by some campaigners against, and objectors to wind farms, largely in regard to the semantic description of AM and its magnitude, and the distinction between cases where AM was believed to be a factor and those where it was a possible factor.

- The wind farm noise may contain greater than anticipated characteristics that may enhance its impacts e.g. excess AM.
- '*Unrealistic expectations'* i.e. the complainants believed that the noise would be less noticeable than it proved to be.
- Complaints may be prompted by planning applications to build other wind farms nearby.

3.18 Discussion

Evidence of the effects of wind turbine noise is strongest for annoyance and sleep disturbance. However, the current state of knowledge on dose response relationships for wind turbine noise is inconclusive and does not enable the derivation of a robust criterion or range of criteria. However, studies carried out in Sweden, Germany and Holland have suggested that annoyance can occur at low levels of exposure to wind turbine noise; although other factors can influence the responses e.g. visual impact of the wind farms. Additionally, studies on the continent suggest that wind farm noise can be more disturbing than transportation and other industrial noise sources.

It may not be safe to extrapolate the dose-response relationships derived from the field studies conducted in Sweden, Germany and Holland to the UK.

The level of background noise against which the wind turbine noise is heard is important because it can mask turbine noise and influence response. Consequently, it is recommended that any assessment of wind turbine noise should consider the influence of background noise.

The presence of acoustic features in the wind turbine noise is an important factor in the degree of impact. An assessment of wind turbine noise should consider both the presence and prominence of acoustic features.

Whilst there are various methods which can potentially be used to assess the tonality of noise emissions, there is little guidance regarding the objective rating of effects attributable to other acoustic features, such as amplitude modulation of aerodynamic noise.

The above review has shown that there is significant uncertainty about human response to wind turbine noise and noise levels. This is not unique for wind farm noise as similar uncertainty exists for other noise sources e.g. industrial noise in general[77]. Consequently, this study is not able to recommend a particular noise rating procedure or to suggest specific critical limits that can be used to objectively assess the effects of wind turbine noise.

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[77] *Berry B & Porter N, DEFRA Report NANR 5 - Review and analysis of published research into the adverse effects of industrial noise, in support of the revision of planning guidance 2004. Included in its recommendations the following:*

1. *Further research should be funded to develop improved descriptors of acoustic features in order to describe and assess noise from industrial sources, that are meaningful in terms of the subjective characteristics that they are supposed to represent.*
2. *A more detailed study should be undertaken on non-acoustic factors, with a view to implementing practical guidance.*
3. *The lack of hard information from the review of previous surveys, and the review of the importance of "change" situations indicate the need to conduct a new survey, or surveys.*

See http://www.defra.gov.uk/environment/quality/noise/research/industrial/documents/execsummary.pdf (last viewed 8th March 2011).

Notwithstanding the absence of definitive Statutory Nuisance noise levels thresholds in statute or case law, it is nonetheless considered that noise measurements and noise criteria can be used to inform and corroborate the professional judgement of expert witnesses and evidence from complainants whether wind turbine noise is causing Statutory Nuisance. As noise measurements can be useful in demonstrating the presence or absence of a problem, and its duration, timing and intensity in an objective and scientific manner independent of the non-acoustic factors that may influence qualitative and subjective judgements.

Additionally, it is common that where a person responsible for Statutory Nuisance relies on “Best Practicable Means” as a ground for appeal or defence against enforcement of an abatement notice; that debate about noise levels will play a significant role in ranking the acoustic efficiency of any reasonably practicable mitigation measures; or in determining to what degree any Statutory Nuisance should be restricted when it cannot be fully abated.

Consequently, in the investigation of noise complaints under the Statutory Nuisance regime it is possible to measure response itself e.g. record and report self-documented effects from the complainant and from others affected by the noise or who witness the noise; and to support these qualitative observations with noise measurements and analysis in order to reinforce the view whether any complaint of Statutory Nuisance is justified.

4 Review of Legislation

4.1 Prevention of Noise Nuisance from New Wind Farms

4.2 Legal Review

4.2.1 Introduction

This legal review considers the position of wind farm development in relation to the regulatory framework intended to protect other users of land, most notably the neighbouring public, from its impact. The principal objective of this review is to assess how local authorities Statutory Nuisance powers may be useful in dealing with noise problems from wind farms.

The early part of the legal review introduces the legal concepts of nuisance and Statutory Nuisance then examines the relevance of the planning system to Statutory Nuisance, followed by more detailed consideration of Statutory Nuisance. This structure has been adopted because planning conditions attached to the development by the local planning authority should provide the initial basis for the effective control of noise. For most types of noise generating development conditions can protect the amenity of the neighbourhood.

The Statutory Nuisance regime acts as a separate system of control from the planning system, using different standards of assessment and control of impact, and thus it seems logical to consider the planning system separately.

Another reason for considering planning issues early on is because the grant of planning permission has an impact on enforcement decisions taken later using the Statutory Nuisance regime. This is because the grant of permission may change the threshold for Statutory Nuisance; because planning permission for a scheme may change the strategic nature and character of the locality so that Statutory Nuisance may be judged differently from the circumstances prior to its development.

As with all forms of development with potential to impact the environment, erode amenity or cause Statutory Nuisance, it is essential that environmental health professionals work closely with planning colleagues if decisions are to be made properly. This has long been recognised as a general problem in the environmental protection field.

The CIEH Noise Management Guide specifically advises that Environmental Health and Planning departments and their staff should work closely to secure appropriate levels of protection for existing noise sensitive land uses and occupiers, as this should normally prevent Statutory Nuisances from occurring.

This review reinforces the necessity for environmental health professionals to engage fully with the planning decision-making process as a proactive means of preventing problems. But it also recognises the importance that Statutory Nuisance enforcement continues to have later when the development is up and running in reactively dealing with unforeseen problems; albeit often to a different standard than achievable under the planning system.

4.3 What is Nuisance?

The common law[78] has long recognised that noise may be a problem, mainly by way of an action for the tort[79] of nuisance.

The rapid urbanisation and industrialisation of much of the United Kingdom in the 18th and 19th centuries later spurred the development of the concept of nuisance which became, and remains, one of the two limbs of Statutory Nuisance.

In England and Wales common[80] law nuisances are divisible into public nuisances and private nuisances; but there is no such distinction in Scotland. The first deals with interferences with the comfort of the general public and is a crime. The latter deals with the unreasonable and substantial interference with the use of property or personal comfort and is a civil wrong (tort) and does not attract criminal liability.

Statutory Nuisances are matters prescribed by statute as such and covers both public and private nuisances and is discussed below.

At common law, the remedies for public and private nuisance are either damages to compensate for the harm which has been done or an injunction to prevent something from happening in the future. In addition, public nuisance is a criminal offence triable either way, that can attract penalties of unlimited fines and up to life imprisonment.

Part III of the Environmental Protection Act 1990, as amended contains the main legislation relating to Statutory Nuisance. It applies in England, Wales and Scotland and is enforced by local authorities. The Public Health (Ireland) Act 1878, as amended, contains the main legislation relating to statutory nuisances in Northern Ireland, under Part II of the Pollution Control and Local Government (Northern Ireland) Order 1978, district councils have powers to deal with noise nuisance.

The remedies for Statutory Nuisance are either an abatement notice or a Magistrates court order with similar effect. An abatement notice is served by the local authority and is a notice which requires the recipient to abate the nuisance and to take such steps or to carry out such works as the authority requires the recipient to do to abate the nuisance. An order by the Magistrates court is broadly similar in effect, even though it has a different name and is made by a magistrates' court on the application of an aggrieved individual. Failure to comply with an abatement notice or a magistrates' court order is a criminal offence.

Local authorities have the power to take proceedings in public nuisance in their own names and these may be considered where the nuisance is particularly serious or where there is a substantial public health risk.

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78 Common law is law made by judges, based on previous court decisions and customs as distinct from statute law created by Parliament.

[79] Tort is an old French word for a "wrong." A tort is a civil wrong. A civil wrong involves a breach of a duty owed to someone else, as opposed to criminal wrongdoing which involves a breach of a duty owed to society. Torts are civil wrongs other than breaches of contract and certain equitable wrongs. Tort usually refers to the causing of damage to property or its use or to a person's reputation or harm to a person's commercial interest

[80] The terms common law and civil law nuisance are interchangeable.

Local authorities will more commonly tackle nuisance in the course of fulfilling their enforcement obligations under section 80 of the Environmental Protection Act 1990, which apply to statutory nuisances.

For a noise to be found to be nuisance in law depends on the circumstances, notably on the effects that the noise has on people and the use of property. Private nuisance in English and Welsh law has been defined as '*the unlawful interference with a person's use or enjoyment of land, or some right over, or in connection with it*[81]. This form of nuisance is a tort, or civil wrong, which recognises the right to use your land/property (sometimes referred to as 'amenity') without unreasonable disturbances from neighbouring property. The standard required to prove that the interference is unreasonable is a high one, so minor problems or mere annoyance or irritation will not be enough to amount to a nuisance in law.

Because private nuisance is a civil action, the remedies available to a successful claimant include an injunction to prevent the nuisance from continuing and an award of damages to compensate for the harm. In England and Wales fault does not need to be proven – strict liability applies i.e. a person can be held liable in nuisance for injury or loss even if they exercised all possible care to prevent it.

The law of nuisance is different in Scotland from the rest of the UK. In Scotland the classic definition of nuisance is found in Bell's *Principles*[82] at section 974, as:

'*whatever is intolerably offensive to individuals in their dwelling-houses, or inconsistent with the comfort of life, whether by stench (as the boiling of whale blubber), by noise (as a smithy in an upper floor) or by indecency (as a brothel next door) is a nuisance'*.

In Scotland, there is no distinction between private and public nuisance, and to be a nuisance the harm or behaviour must be more than can be reasonably tolerated - '*plus quam tolerabile*' (more than tolerable).

In Scotland, to be liable for a nuisance a person must be at fault or to blame (*culpa*) To what extent, if any, it is necessary to prove that the defender was at fault in creating the relevant noise nuisance has not yet been authoritatively determined by the courts. However, a good working rule in order to ascertain if the defender is culpable would be whether a reasonable person would have avoided creating the noise in question.

In practice there is little difference in terms of Statutory Nuisance between Scotland and the rest of the UK, because:

- Scottish definition of nuisance refers to the matter being more than can be reasonably tolerated i.e. not limited to the tolerances of the most sensitive.

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[81] *Read v Lyons and Co. Ltd [1945] KB 16 and [1947] 2 All ER 197 at pg 199, quoting in approval Winfield, Textbook on the law of tort (3rd Ed) pg 426*

[82] George Joseph Bell, Professor of Scots Law at Edinburgh University, Author of: Principles of the Law of Scotland, 10th ed, 1899 Edited by William Guthrie, Advocate – available as a public domain open source from http://www.archive.org/details/BellPrinciplesOfTheLawOfScotland10thEd1899 (Last viewed 8th March 2011)

- The reference to something not being a nuisance if it is conveniently done in the "reasonable user" defence available in English Law, does not mean convenient only to the person carrying out the matter complained of. It means convenient in the circumstances, including the potential or actual impacts on others.

Further guidance on the use of the Statutory Nuisance powers of the Environmental Protection Act 1990 can be found in the - Health Protection Scotland Guidance Note[83].

In England and Wales some nuisances are so widespread that they amount to public nuisances. In *A-G v PYA Quarries Ltd, Denning LJ* [at 190–1] defined public nuisance as a nuisance which is so:

"*widespread in its range or so indiscriminate in its effect that it would not be reasonable to expect one person to take proceedings on his own responsibility to put a stop to it, but that it should be taken on the responsibility of the community at large*."

So, if a class of people or a neighbourhood suffers to an unreasonable extent from noise emanating from a person's land, then a public nuisance prosecution could be brought by the local authority or by a private individual against the person responsible. As with private nuisance, an injunction could be sought in the High Court or in the county court to prevent reoccurrence of the nuisance.

There is no distinction between public and private nuisance in Scottish common law.

4.4 Statutory Nuisance

Statutory Nuisances are matters declared as such by legislation. The primary legislation declaring Statutory Nuisances is the Environmental Protection Act 1990 (EPA'90), which consolidated many Statutory Nuisances from different legislation e.g. the Public Health Act 1936 and Control of Pollution Act 1974.

Section 79(1)(g) of the EPA'90 provides that: '*noise emitted from premises and being prejudicial to health or a nuisance*' shall constitute a Statutory Nuisance. This wording indicates that there is a two-limbed structure to the provision: either prejudicial to health or a nuisance. This provision in its original form only applied to England and Wales. However, since 1995, sections 79-82 of the EPA'90 have also applied to Scotland. Part 3 of the EPA'90 does not apply to Northern Ireland, where the Statutory Nuisance regime for noise is provided by Part 3 of the Pollution Control and Local Government (Northern Ireland) Order 1978. The principal difference is that in Northern Ireland there is no prejudicial to health limb of noise Statutory Nuisance. Otherwise, these are similar or equivalent provisions to those applying in Great Britain.

Because the EPA'90 does not include a definition of nuisance it is worth considering whether case law helps in assessing whether an activity or operation can be a Statutory Nuisance under the EPA'90. In this

[83] http://www.documents.hps.scot.nhs.uk/environmental/guidance-notes/neighbourhood-noise.pdf (last viewed on the 8th March 2011).

regard the case of *R v. Carrick District Council ex parte Shelley [1996] Env.L.R. 273,* is helpful as Carnwath J. said:

"*The word "nuisance" has given rise to more controversy, in the context of the Public Health Act 1936 and its predecessor. In principle "nuisance" has its common law meaning, either public or a private nuisance*".

In order to be a Statutory Nuisance something must be either capable of being a private or public nuisance[84]. However the term is also narrower than at common law, for example the term Statutory Nuisance has been discussed as follows:

"*I think the legislature intended to strike at anything which diminished the comfort of life though not injurious to health [and at anything which would in fact injure health*]"[85]

This does not mean that a matter must be injurious to health to be a Statutory Nuisance [86]; just that there should be at last a tenuous link to health; which can be satisfied by adverse impacts on personal comfort, the matter being described in a leading judicial decision[87] as follows:

"*These words [personal comfort] are appropriate enough in the context of what is a "nuisance" in the Public Health Act 1936[88] … but they are quite inappropriate in relation to the other limb "prejudicial to health". Health is not the same as comfort and interference with the latter does not bring a case within the health limb….* "

This difference between common law and Statutory Nuisance has been described as being: "distinction between harm to property is not protected by Statutory Nuisance and harm to people [that] is" [89]

The basic structure of the Statutory Nuisance enforcement regime is that, other than where the Statutory Nuisance arises from a structural defect or the person responsible cannot be found, it requires a local authority to serve an abatement notice on the "*person or persons responsible for the Statutory Nuisance*", where it is satisfied that a Statutory Nuisance exists in its area, or is likely to occur or recur. Failure to conform to the requirements of an abatement notice is a criminal offence.

An individual may complain to the magistrates' court if they are 'aggrieved' by the existence of a statutory nuisance, and if the court is satisfied that the nuisance exists or is likely to recur, it must make an order requiring abatement or prohibiting recurrence of the nuisance under section 82 of the EPA.

Noise may constitute a Statutory Nuisance in two ways because section 79 of the EPA provides a two limbed structure (though not in Northern Ireland). The nuisance limb includes both private and public forms of nuisance; both these are sometimes referred to as 'common law' nuisance because they are creatures of case law. Under the nuisance limb of Statutory Nuisance, the complainant is not required to

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[84] National Coal Borad Vs Neath Borough Council (AKA Thorne) [1976] 2 All ER 478, R V Carrick DC ,ex P Shelley [1996] Env LR 273, Godfrey Vs Conwy CBC [2001] Env LR 674, LB Camden Vs LUL [2000] Env LR 369 & Murdoch Vs Glacier Metal Co Ltd [1998] Env LR 732..

[85] Bishop Auckland Local Board Vs Bishop Auckland Iron & Steel Co (1880) 10 QB 138 – Endorsed by Lord Wilberforce in Salford City Council V McNally [1976] AC 379.

[86] Godfrey Vs Conwy CBC[2001] Env LR 674

[87] Salford City Council V McNally [1976] AC 379.

[88] The precursor to, and incorporated into the Environmental Protection Act 1990

[89] Statutory Nuisance, McCraken, Jones, Pereira & Payne [2001], Pub - Butterworths ISBN 0 406 92673 5 – at pg 4 para 1.07

have a proprietary interest in land which neighbours the source of the nuisance (which would be a requirement for a civil action in private nuisance). The nuisance is required to '*be one interfering materially with the personal comfort of the [person], in the sense that it materially affected their well-being*'[90].

The prejudicial to health limb of section 79 would be triggered where there was a significant risk of injury to health arising from the noise or if actual injury to health resulted[91].

4.5 Enforcement Action Using the Statutory Nuisance Regime

Statutory Nuisance regulation is largely a reactive way of dealing with noise problems, after a scheme becomes operational. In a limited way it can also deal with potential problems, but only once a scheme is in place. Thus the abatement notice procedure under section 80 EPA 1990 can be utilised to control Statutory Nuisances that are likely to occur or recur as well as those that are present when the notice is served on the person responsible.

The local authority can also stop or restrict Statutory Nuisances by seeking an injunction in the High Court under section 81(5) EPA'90.[92], although case law suggests that injunctions will not be granted before an abatement notice has been served. This power can be used for any statutory nuisance but is typically used where a severe problem exists and the person responsible is refusing to co-operate or even intensifies the problem. The power to seek injunctions in the EPA'90 is separate from those local authorities have under by section 222 of the Local Government Act 1972 to obtain an injunction in the county courts or in the High Court to control a public nuisance.

Civil remedies under the tort of private nuisance – abatement, injunctions and damages - may be available to persons affected by wind farm development, should they bring a private action in the courts.

4.6 Legislative Background of Statutory Noise Nuisance

Section 1 of the Noise Abatement Act 1960 introduced noise nuisance, for England and Wales, into the framework provided by the Public Health Act 1936. The Noise Abatement Act 1960 also applied in Scotland where it was enforced under the Public Health (Scotland) Act 1897. This regime was replaced by the Control of Pollution Act 1974, the statutory nuisance parts of which were later repealed in England and Wales by section 162 of, and Schedule 16 to, the EPA 1990. In Northern Ireland noise nuisance comes within the scope of the Pollution Control and Local Government (Northern Ireland) Order 1978.

In England, Wales and Scotland Section 79(1)(g) of the EPA 1990 is the current statutory provision regulating noise Statutory Nuisance, though noise on construction sites is also governed by sections 60 and 61 of the Control of Pollution Act 1974. In 1993, a new provision was added to section 79(1), paragraph (ga) which introduced noise caused by a vehicle, machinery or equipment in a street. The Control of Pollution Act 1974 was the first Act enabling enforcement action to take place regarding

[90] *Wivenhoe Port v Colchester BC [1985] J.P.L. 175*
[91] Although the risk of or actual physical injury is not covered – *See: R v Bristol CC, ex p Everett [1999] 2 All ER 193; Env LR 587.*
[92] *The Barns (NE) ltd & Shaban Suleman v Newcastle upon Tyne City Council (2005) [2005] EWCA civ 1274*

prospective nuisances - that is noise nuisances that are ‘likely to occur or recur’. This duty to take action with regard to future nuisances now applies to all forms of nuisance covered by section 79 of the EPA 1990.

4.7 Noise and Statutory Nuisance: the Objective Test in Law

Whereas to the lay person anything that annoys is a nuisance, the legal test for noise nuisance is objective. That is not to say that the noise must exceed a specified noise level, rather that the noise must unreasonably affect the ordinary use of property or personal comfort of persons who are not unduly sensitive i.e. the noise must be both excessive and unreasonable. The classic test for reasonableness is objective. In Walter v Selfe[93] the Court posed the question colourfully:

“*ought this inconvenience to be considered as more than fanciful, in fact, as more than one of mere delicacy or fastidiousness;, as an inconvenience materially interfering with the ordinary comfort physically of human existence, not merely according to elegant or dainty modes of living, but according to plain and sober and simple notions among the English people*?”

Probably more than for any other form of Statutory Nuisance, with noise there are wide variations between the perceptions of individuals and their ability to tolerate it. Much depends on the individual affected, their lifestyle and on other aspects of their life and the circumstances giving rise to the noise and in which it is heard. However, the law of nuisance and Statutory Nuisance can only protect the ordinary use of land and persons who are normally sensitive to noise. The objective standard the court will apply in deciding if something is a nuisance is that described above, which although the language is somewhat dated the principles still apply. If a plaintiff is particularly sensitive to a type of nuisance, it is not actionable unless one can show that the nuisance would have affected a "reasonable" person. What is the thinking behind this principle? The Court's view is that a person should not be able to increase his neighbour's liabilities because they carry out special activities on their premises[94] or are more than ordinarily susceptible to the matter complained of[95].

The decision as to whether a Local Authority is satisfied that a complaint or a situation amounts to a Statutory Nuisance usually falls to sufficiently trained and experienced Environmental Health staff making the decision on behalf of the Local Authority. In Rottenberg[96] five employees of the London Borough of Hackney were involved in making the decision that the chanting, shouting and banging on the floors in a synagogue and school were responsible for causing a nuisance to the neighbour separated from those premises by a party wall. Rottenberg came to the High Court as a case stated by the council against the decision of the Crown Court to allow an appeal against conviction in the magistrates’ court for six offences of breach of an abatement notice. The Crown Court had taken into account the fact that the local authority had granted planning permission for a religious school and synagogue to be formed from a semi-detached suburban house and that the noise was relatively short lived and infrequent and had not

[93] *Walter -v- Selfe (1851) 4 De G & Sm 315*
[94] *Robinson -v- Kilvert (1889) 41 Ch.D. 88 D*
[95] *Devon Lumber Co. Ltd. -v- MacNeill (1987) 45 DLR (2nd) 300*
[96] *R (on the application of Hackney London Borough Council) v Moshe Rottenberg (2007) [2007] EWHC 166 (Admin)*

been persuaded by evidence provided by the Council officers. The High Court found that the Crown Court had correctly decided this issue and added that the Court's decision about noise nuisance over rode that of the Council officers. In the words of Mr. Justice David Clarke [at para 20]:

"*Just as in the Crown Court, where it is well-established by Stockwell and other cases that a jury is not obliged to accept the evidence of any particular witness, including that of an expert witness, even if unchallenged by other experts; so also are a judge and justices sitting on appeal from a Magistrates' Court. Whether the noise on these occasions was a Nuisance so as to constitute a breach of the abatement order was a matter of fact for them to be decided on the evidence. In my view, the fact that a subjective judgment is involved, as Mr Butler has been at pains to submit, is not an argument which assists his cause. The subjective judgment in the end is that of the court. If the standard were an objective one, to be measured by some yardstick such as the level of decibels of noise at particular times of day, the case might have been very different. But such a regime of objective measures would have to take into account so many different factors as to be quite unworkable, and there is no such objective standard prescribed by Parliament*."

In effect the Court stated that the Local Authority had not persuaded the Court that Statutory Nuisance had been caused; and because parliament had not specified a measurable noise level or any other factor (either quantitative or qualitative) as the threshold of Statutory Nuisance; the court was not bound to accept the expert evidence of the Local Authority officers, or of any other witness, and it was for the Court to make judgment as to whether the noise constituted a nuisance.

Rottenberg demonstrates that the qualitative nature of the Court's decisions on nuisance means that the concept does not readily lend itself to articulation by way of fixed noise level based criteria or any other prescriptive measures. The flexible nature of the concept of nuisance and the tests for establishing it were neatly articulated by Pollock CB in Bamford v Turnley[97] where he stated:

"*I do not think that the nuisance for which an action will lie is capable of any legal definition which will be applicable to all cases and useful in deciding them. The question so entirely depends on the surrounding circumstances, the place where, the time when, the alleged nuisance, what the mode of committing it how, and the duration of it, whether temporary or permanent, occasional or continual, as to make it impossible to lay down any rule of law applicable to every case and which will also be useful in assisting a jury to come to a satisfactory conclusion, It must at all times be a question of fact with reference to all the circumstances of the case*."

Consequently, whilst noise measurements can be useful, they are not are not always required or over riding of qualitative evidence or subjective decision making in regard to Statutory Nuisance. For example in a recent case the High Court commented in regard to expert acoustic evidence for and against an alleged noise nuisance from stockcar, speedway and off road motor biking that[98]:

[97] *Bamford -v- Turnley [1862] LR 3 B&S 62*
[98] *Lawrence & Shields v Fen Tigers Ltd and David Coventry Trading Ltd & 5 Ors; [2011] EWHC 360 (QB)*

"As it seemed to me (Judge Richard Seymour Q.C.), the value of the expert evidence related to whether, on the assumption that I accepted the evidence of the claimants as to the effect upon them of the noise generated by the activities at the Stadium and the activities at the Track, a reasonable person would have been similarly affected."

In this case the judge clearly saw the evidence of those affected by the noise as being paramount and the technical acoustic evidence only having a supporting role in assisting in his judgment of nuisance.

It also reinforces the importance for local authorities of ensuring that the decision about whether a situation amounts to a Statutory Nuisance must be taken carefully by individuals with sufficient training and expertise, who meticulously record the grounds and reasons for forming a view whether Statutory Nuisance applies. This helps maximise the influence their evidence may have on the Court's view of whether Statutory Nuisance applies.

4.8 Scope of Section 79(1)(g) of the EPA '90 and Wind Farms

The provisions regarding noise nuisance are contained in section 79(1)(g) of the EPA'90, which states that a Statutory Nuisance occurs as a result of '*noise emitted from premises so as to be prejudicial to health or a Nuisance*'. Vibration is included in the definition of noise. It is a requirement for the noise to be emitted from 'premises', which includes land and vessels.

'Land' includes any buildings or other structures, and also includes land covered with water. Does this mean that an offshore wind farms operate from 'premises' coming within the scope of the EPA'90? The position is uncertain since the Act does not refer to offshore sites and arguably Parliament intended the Statutory Nuisance provisions to apply only to territorial land. There is an exception in that section 79(11) EPA 1990 does include the territorial sea lying from the shore as part of the area of a local authority, so enabling it to take enforcement action where an off-shore wind farm lies in such a location.

4.9 Links to Private Nuisance

Most instances of noise Statutory Nuisance tend to fall under the nuisance limb, akin to a private nuisance. Noise from commercial wind farms, provided it meets the nuisance threshold, is only likely to comprise a public nuisance where a sufficient class of the public is affected. However, in a case brought by '*aggrieved persons*'[99] against the companies operating a wind farm under section 82 EPA 1990, no point seems have been taken concerning the type of nuisance as the case was based on the Statutory Nuisance provisions of the legislation. The link to private nuisance means that the noise has to be emitted from a separate property from the complainant's, and substantially interfere with the victim's enjoyment of their property or personal comfort. Besides residential occupiers, this can include business or other non-residential occupiers. In the tort of private nuisance, 'enjoy' refers to the exercise and use of the rights to occupy land and having the full benefit of that right, rather than deriving personal pleasure from it.

[99] The Section 82 EPA'90 Case of Powergen Renewables Limited and Wind Prospect Limited (South Lakeland Magistrates' Court, 20 January 2004).

Private nuisance is thus a property tort. The person bringing a civil action in damages or who is seeking an injunction is required to have a proprietary interest in land. The civil wrong is different in Statutory Nuisance and amounts to the right of a wider category of individuals not to suffer material personal discomfort arising from any of the matters set down in section 79 EPA 1990. Accordingly, the noise victim need not be the owner or somebody having exclusive possession of the property and could be any person sufficiently affected by the noise, including business occupiers or visitors. *Wivenhoe Port v Colchester BC*[100] was an appeal brought in the Crown Court against the magistrates' decision, in which the judge concluded that:

"*to be within the spirit of the Act [section 79 EPA 1990] a nuisance to be a Statutory Nuisance had to be one interfering materially with the personal comfort of the residents, in the sense that it materially affected their well-being, although it might not be prejudicial to health*."

The grounding of the nuisance limb of section 79 EPA'90 in the concept of 'personal comfort' and the wider class of persons founding an action as compared with the tort of private nuisance, suggest that this limb is in reality based on protecting a personal right rather than a proprietary right. This interpretation is further supported given the class of persons with sufficient standing needed to bring an action under section 82 EPA '90, namely 'persons aggrieved' by the nuisance.

4.10 Links to Public Nuisance

A Statutory Nuisance may also be a public nuisance[101]. In order to be satisfied that noise from wind farms constituted a public nuisance, it would be necessary to prove that the noise materially affected the comfort and quality of life of a 'class' of the public. 'Class' is not precisely defined, but it implies a substantial number or a section of the public being affected by the nuisance, even if not all suffer to the same degree. The following examples show how the question of the "class of person" varies on a case by case basis.

When the inhabitants of three chambers in Clifford's Inn complained of noise caused by a tradesman, it was held that an indictment for public nuisance will not lie for a nuisance suffered by only a few inhabitants; if there was a nuisance it could only be a private nuisance.

Whereas the situation where potentially dozens of local residents up to a 100 metres from a public house in central London were regularly affected by noise from large numbers of persons gathered on the highway outside the pub regularly made substantial noise until late at night was upheld as a public nuisance in the case of *R (Hope & Glory) v Westminster Magistrates (2009)* [102] Here it was determined that, in order to qualify as a public nuisance, the disturbance must be *'sufficiently widespread'* and *'amount to more than a private nuisance'*.

[100] *Wivenhoe Port -v- Colchester BC [1985] J.P.L. 175*
[101] NB: *In Scottish law there is no distinction between private and public nuisance at common law, although the term public nuisance is used in licensing legislation for this country.*
[102] Neutral Citation Number: [2009] EWHC 1996 (Admin) Case No. CO/5324/2009

It is clear from case law that a decision needs to be made on a case by case basis. However, it can be understood that:

(a) The common law definition of public nuisance should be applied by the authorities;

(b) Whether or not a public nuisance is 'public' in nature will depend upon whether there is effect on a sufficiently large number of members of the public *or* whether there is a sufficiently widespread or indiscriminate effect.

Public nuisance would be an appropriate cause of action with regard to serious instances of noise pollution, where the public at large are victims rather than a limited number of individuals. The availability of prison sentences and fines (unlimited in the Crown Court) make it a more serious offence than Statutory Nuisance..

Local authorities generally restrict themselves to using their enforcement powers under section 80 of the EPA 1990, whether the nuisance limb amounts to a public or a private nuisance. Remedies for Statutory Nuisance include obtaining an injunction in the High Court and this course is available where use of ordinary abatement notice proceedings has proved ineffective.

4.11 Noise and Prejudice to Health

The definition of statutory nuisances (in section 79 EPA'90) has two limbs. The nuisance must be either prejudicial to health or a nuisance.". Most noise Statutory Nuisances consist of a form of private nuisance; more widespread ones may be public nuisances. Recourse to the health limb is likely to be rare in respect of noise. Is the health limb redundant therefore? Normally the standard required to demonstrate prejudice to health is higher than for nuisance; usually this implies that the problem is more serious than where health effects are absent.

The prejudicial to health limb did not appear in the Control of Pollution Act 1974, the preceding legislation to the EPA 1990 with respect to noise nuisance. Neither does it apply at present in Northern Ireland: the legislation now in force - the Pollution Control and Local Government (Northern Ireland) Order 1978 - having been drafted in line with the Control of Pollution Act. During the final reading of the Environmental Protection Bill, the Government saw the inclusion of an 'injury to health' limb as an important extension to the law Statutory Nuisance in regard to noise.

The 'health limb' and the 'nuisance limb' are alternatives within section 79(1) EPA 1990. Most noise Statutory Nuisances consist of a form of private nuisance; some particularly serious ones may be public nuisances. Recourse to the health limb is likely to be less than for the nuisance limb in respect of noise because the standard required to show prejudice to health is higher than for nuisance; as was said in *Birmingham CC v Oakley* [2001] 1 All ER 385, 399, "prejudice to health" "*covers what may be actually*

injurious as well as what may be likely to be injurious [but is] in either case something over and above what may be seen as a "nuisance".

Nevertheless, if the health effects are sufficiently serious and can be proved then it can be better to proceed under the health limb than under the nuisance limb because this better reflects the reality of the situation and the "best practicable means defence" does not apply to the health limb of Statutory Nuisance. In certain cases, of course, recourse to the health limb may be the only option since this does not require, as the nuisance limb does, evidence of an interference with a person's lawful of property or personal comfort.

Proceeding under the health limb presents a second difficulty, however, arising from the state of the law. Arguably, the health risk must be of a type which is a '*threat of disease, vermin and the like'* to engage the health limb. This is currently the position with Statutory Nuisances arising from accumulations or deposits[103] and from the state of premises.[104] These forms of Statutory Nuisance originated in the mid-nineteenth century, when Parliament intended that the health limb be used to control threats to public health arising from diseases and unsanitary conditions.[105] The origin of noise Statutory Nuisance is more recent – the first legislation dating from the Noise Abatement Act 1960. It is a moot point whether courts would interpret noise nuisance in the same way as they have done with these older, public health nuisances. There is no decided authority on the point and so an element of uncertainty exists concerning the utility of the health limb of Statutory Nuisance in respect of noise. The better view is that the health limb of noise Statutory Nuisance should not be interpreted in limited terms based on a nineteenth century public health paradigm. The alternative view could make the health limb "*otiose*" i.e. superfluous or useless in regard to noise Statutory Nuisance[106].

In practice, excepting noise induced sleep disturbance, it can be hard to prove that a noise nuisance is prejudicial to health as the evidence of impacts on physical health is still emerging and not yet settled, and as described earlier some of the less direct health effects such as annoyance and interference with well being may not be included in the "sanitary" remit that the Courts have recently applied to the concept of prejudicial to health. Nonetheless, any future advances in knowledge about the health effects of noise, particularly where these consist of continual exposure to fairly low levels, could be highly relevant.

Chapter 3 summarises the findings of a review of the effects of wind farm noise. There is no guidance in the EPA'90 or from court decisions about how serious injury to health needs to be in order to fall within the statutory definition. However, there is an accumulating body of scientific literature concerned with the effects of persistent noise on health. As with most factors which amount to a health risk, the causal chain

[103] Coventry CC v Cartwright [1975] 2 All ER 99.
[104] R v Bristol CC, ex p Everett [1999] 2 All ER 193; Env LR 587.
[105] R. Malcolm & J. Pointing, Statutory Nuisance: Law & Practice (2002, OUP), chapters 3 and 4.
[106] Godfrey v Conwy County Borough Council [2000] EWHC Admin 443

is not simple: whether it is noise which causes any injury will be a matter for expert evidence and will ultimately be an issue for the Court to decide.

4.12 Wind Farms, Noise Nuisance and the Planning System

Local planning authorities are expected to accommodate proposals for renewable energy. Government advice on how to do so is set down in the relevant Planning Policy Statement for the appropriate nation; for example in:

- England – PPS 22 (and companion guide)
- Scotland - PAN 45
- Wales – TAN 8 Pt 2
- Northern Ireland – PPS 18

The planning and permitting systems put in place by government to regulate the construction and operation of wind farms; and in regard to noise "*to provide a reasonable degree of protection"* depend on striking a compromise between conflicting uses of land, in the public interest. For some persons who reside near to commercial wind farms – or who in due course will find themselves in this position – there may never be a satisfactory solution to noise emanating from wind farms.

4.13 Planning Act 2008

The 2008 Planning Act was to have major implications for the planning of energy generation and this includes the provision of new wind farms. Authorization for allowing the construction and operation of new wind farms above a certain size came within the scope of Part 3 of the Act. Included within the scope of these are generating stations of over 50 megawatts capacity onshore in England and Wales and of over 100 megawatts for offshore installations. Economies of scale, combined with the need to secure a significant increase in the supply of energy from renewable sources, plus the benefits to the promoters of new schemes - especially in respect of the speed of obtaining national planning approval - may mean that a significant proportion of the new demand for energy is likely to be met by NSIP schemes. However, new developments below the capacities set out above will be attractive to small scale developers, possibly aimed at serving a specific location or user; and these continue to be regulated by local planning authorities. Therefore it is anticipated that many wind farms, as well as micro-wind generation facilities, will become and remain under local planning authority control.

The Planning Act 2008 has established a national body - the Infrastructure Planning Commission (IPC) - to grant permissions for the construction of NSIPs to replace local authority planning control. Section 158 of the Act provides a defence of Statutory Authority to the developers of projects and to the companies that operate them. This means that unless negligence can be proved and providing that the operator keeps within the conditions set down in the authorisation, actions for civil and criminal forms of nuisance were unlikely to be successful.

However on the 1st July 2010 The Government confirmed that the Infrastructure Planning Commission (IPC), the organisation with the power to approve major infrastructure projects, will be abolished. Instead a Major Infrastructure Planning Unit will be established in the Planning Inspectorate to consider major infrastructure proposals such as offshore wind farms and nuclear power stations. It has been stressed that meanwhile Ministers would take decisions on applications within the same statutory fast-track timeframe as the current regime, which will need primary legislation before it can be abolished. In addition, as previously, all National Policy Statements (NPS), the Government's future infrastructure blueprints, will be subject to ratification by Parliament; and the replacement system will be more democratically accountable.

However, until the primary legislation is in force, the IPC will continue to consider and determine applications as NPSs are designated to ensure there is no delay in handling applications. In the interim, the IPC and the Planning Inspectorate will consider how they can work together and identify efficiency savings. The Government has signalled it will press ahead with the development of NPSs and will issue a more detailed statement on them later in 2010.

The Government has insisted it wants to have NPSs in place as rapidly as possible. The Government intends to complete the process for making the energy (including nuclear) NPSs, which are part-way through the scrutiny process, and will bring forward revised final texts and ask Parliament to ratify them.

However, whilst the future operation of the planning system in regard to these strategic developments, it appears that Statutory Authority will only be a defence against Statutory or civil nuisance action, not an exemption; and that complaints should still be investigated and abatement notices served if Statutory Nuisance established.

4.14 Statutory Nuisance and Planning Conditions

All forms of nuisance provide a means – in many ways a '*rough and ready'* process - for reconciling conflicting users of land. Notwithstanding Local Authority's duty and power to proactively seek out nuisance, which in practice are little used; it can be seen as a reactive system of control, dealing with complaints that arise after permitting or planning decisions have been made. Unfortunately, for many forms of development the planning process does not always prevent complaints from being made or indeed prevent Statutory Nuisances from occurring. Whilst normally the planning system seeks to protect amenity to a more stringent standard than can often be achieved under Statutory Nuisance powers; complaints may still arise after planning permission has been granted because the planning conditions have not provided sufficient control or are unenforceable due to defective wording or do not cover an unforeseen noise problem or aggravating element of the noise emitted from the scheme. Additionally sometimes residents affected by the development have high, perhaps overly high, expectations about amenity or are more than ordinarily sensitive to noise or whose thresholds of tolerance have been eroded to lower than normal by non-acoustic factors; and sometimes the operation of the facility produces impacts that had not been fully anticipated or considered at the planning stage of the development. These

are not problems unique to wind farms, and can arise in regard to many other forms of noise generating development.

Statutory Nuisance law is in practice essentially reactive and occupies a different place in regulating environmental harms than planning decisions, which aim to anticipate these harms and limit them by imposing conditions and other planning controls e.g. legal agreements.

The relevant overall guidance for planning decisions in regard to noise made by local authorities are set down in government policy and advice, for example

- In England: Planning Policy Guidance 24: Planning and Noise (PPG 24)
- In Scotland: Planning Advice Note 1/2011 – Planning and Noise
- In Wales Technical Advisory Note 11 - Noise
- In Northern Ireland: No overarching policy - development specific guidance provided.

Whilst the detail of each nation's guidance varies the advice typically gives guidance on the use of the planning system to minimise the adverse impact of noise without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens of business.

Planning conditions play a vital role in ensuring that new development is appropriately controlled. Guidance on the use of conditions is based on Circular 11/95 in England and Wales, Circular 4/1998 in Scotland and PPS 1in Northern Ireland; which establish the criteria that should be used to test the soundness and validity of planning conditions. Conditions should not be imposed unless they are both necessary and effective, and do not place unjustifiable burdens on applicants. They should only be imposed where six tests are satisfied, namely where the conditions are:

i. necessary;
ii. relevant to planning;
iii. relevant to the development to be permitted;
iv. enforceable;
v. precise; and
vi. reasonable in all other respects.

The planning system seeks to avoid prejudicing or placing excessive or unjustifiable burdens on developments such as wind farms, although it should be recognised that such developments inevitably cause noise and the planning authority must ensure that the development does not cause noise that is unacceptable. In striking a balance between these imperatives, it is not required that the planning authority imposes restrictions to reduce noise levels to the minimum possible level irrespective of cost

In addition to planning conditions, the use of planning agreements[107] or unilateral undertakings can provide important public benefits associated with development proposals. They are commonly used to further the objectives of sustainable development as detailed in relevant local, regional and national planning policies. Where an authority's planning objectives or developer's aims cannot be achieved by imposing a planning condition (because, for example, they require the developer to make a financial contribution, or they relate to development, roads or buildings other than those covered by the planning application), it may be appropriate to enter into a planning obligation.

However, in regard to wind farms, planning policy across the UK guides the planning authorities towards using ETSU-R-97 as the appropriate means of rating and assessing noise from wind farms for planning purposes. This document is explicit in stating that it does not seek to protect (existing) amenity; rather its objective is to provide a "*reasonable degree of protection*". ETSU seeks to do this by imposing lower absolute noise limits in quiet environments derived from guidance regarding day time activity and night time sleep disturbance, and in noisier environments limiting the wind turbine noise to no more than 5 dBA above the existing L_{A90} background noise level, at wind speeds from 4m/sec to 12m/sec. In circumstances with an existing quiet environment this can lead to a significant increase in noise levels and erosion in the acoustic and residential amenity of an area. Whether Statutory Nuisance powers can be used to counter this situation will depend on whether the resulting increase in noise results in material interference with the ordinary use of property or personal comfort in England and Wales and Northern Ireland; or is more than ordinarily tolerable in Scotland (as such any increase is unlikely to be prejudicial to health as the final resulting noise level will still be relatively low). Where such a case can be made, whilst taking care not to rely on the use of property of personal comfort or degree of tolerance being more than normally sensitive to noise; the enforcing authority would still need to demonstrate that the current level of noise was unreasonable in the context of the nature and character of the locality with the wind farm present; not as it previously was without the development.

The imposition of planning controls does not mean that the enforcement procedure provided by the Statutory Nuisance regime becomes redundant. Planning and Statutory Nuisance are distinct and separate regimes: each has its own concepts, applications and enforcement mechanisms.

Nevertheless, because both Planning and Statutory Nuisance can cover noise from wind farms; proactively in the case of Planning prior to the development taking place, and reactively in regard to Statutory Nuisance once a scheme becomes operational; there can be an overlap between the two regimes. Whilst appropriate control of noise at the planning stage can prevent statutory nuisance; although compliance with the planning conditions does not on its own provide a defence against alleged statutory nuisance. However, the reactive use of the Statutory Nuisance route would be less challenging

[107] *Commonly called planning obligations and made under section 106 of the Town & Country Planning Act 1990 in England and Wales, Section 75 of the Town & Country Planning (Scotland) Act 2006 in Scotland; and Article 40 of The Planning (Northern Ireland) Order 1991 in Northern Ireland*

where planning conditions either had become insufficient because of a change in circumstances, or where from the start they did not provide adequate control e.g. did not suitably protect a specific location, or did not cover a particular factor that has given rise to the Nuisance e.g. unanticipated intrusive and disturbing acoustic characteristics in the noise emitted by the scheme. It must be remembered, though, that for a statutory nuisance to exist the effect normally has to be greater than that which would otherwise be permitted under planning – where protection of amenity is usually the aim.

The literature review within Chapter 3 explains that, like many noise sources, there is a degree of uncertainty about the effects of wind farm noise. In line with virtually all other forms of noise generating or sensitive development, it is therefore possible that predictive noise assessments can under-estimate the scale of the actual impacts for a wind farm or turbine (although in practice most predictive models either tend to over predict[108] or the user modifies the inputs to model reflect likely worst case scenarios as a means of compensating for this uncertainty). In such circumstances it is possible that Statutory Nuisance action could be taken where the local authority is satisfied that the noise was giving rise to unreasonable material interference with the ordinary use of property or personal comfort i.e. nuisance; or was likely to be injurious to health i.e. prejudicial to health; and therefore a Statutory Nuisance. This would be likely to only become evident once the development is in operation.

4.15 Environmental Impact Assessment

Legislation across the UK, which transposes EU directives 85/337/EEC and 97/11/EEC requires an environmental impact assessment (EIA) for certain types of development before planning permission can be granted[109].

The legislation allows for developers to seek a “screening opinion” from the planning authority to determine whether an EIA is required; and a scoping opinion as to what the EIA should cover e.g. spatial and temporal range, and topics to be included.

For a limited number of projects, such as major power stations, EIA is required in every case. In regards to a wider range of developments, including production of electricity, steam and hot water, where the area

[108] The ISO 9613-2 algorithm is the commonest used wind farm noise propagation prediction method in the UK, and is the most robust according to the findings of a joint European Commission research project into wind farm noise propagation over large distances. The title of the research project was ‘Development of a Wind Farm Noise Prediction Model’, JOULE project JOR3-CT95-0051. This study found that the ISO 9613-2 model was found to be the best available, both in flat and complex terrain. This model tends to over-estimate the noise at nearby dwellings, rather than under-estimate it. The study concluded that the ISO 9613-2 algorithm tended to predict noise levels that would generally occur under downwind propagation conditions i.e. favourable to propagation of noise. and the probability of non-exceedance of the levels predicted by the ISO 9613-2 algorithm was around 85%. Another important outcome of the research was to clearly demonstrate that under upwind propagation conditions between a given receiver and the wind farm the noise immission level at that receiver will be as much as 10 dB(A) to 15 dB(A) lower than the level predicted using the ISO 9613-2 algorithm.

[109] Information of the EIA regs and processes can be found at:
For England and Wales at http://www.communities.gov.uk/publications/planningandbuilding/circularenvironmentalimpact
For Scotland at http://www.scotland.gov.uk/Topics/Built-Environment/planning/National-Planning-Policy/themes/enviro-assessment/eia ;
For Northern Ireland at http://www.doeni.gov.uk/niea/land-home/plan/eia.htm (All last viewed 8th March 2011).

of the development exceeds 0.5 hectare an EIA is required if the proposal is likely to have "*significant environmental effects*" on the environment by virtue of factors such as its nature, size or location.

The EIA legislation does not define what is are "*significant environmental effects*" but typically the legislation requires that an Environmental Statement should include the following:

- A description of the likely significant effects of the development on the environment, which should cover the direct effects and any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the development, resulting from:

  (a) the existence of the development;

  (b) the use of natural resources;

  (c) the emission of pollutants, the creation of nuisances and the elimination of waste,

- And, the description by the applicant of the forecasting methods used to assess the effects on the environment.

Where EIA is required, the likely effects of noise will be one of the considerations needing to be addressed in the environmental statement prepared by the developer and subsequently submitted to the planning authority with the planning application. The environmental statement must describe the likely significant effects of the development on the environment as well as a description of the measures proposed to prevent, reduce and where possible offset any significant adverse effects on the environment. In addition, the environmental statement should provide an indication of any difficulties encountered by the applicant in compiling the required information. Besides technical deficiencies, the environmental statement should also address issues of scientific uncertainty.

4.16 Compliance with Planning Permission and the Nuisance Limb of Statutory Nuisance

A central nuisance issue in wind farm development subject to local authority planning control is whether the grant of the permission authorises any nuisances arising from the development, assuming that it keeps within the scope of the permission.

Planning permission is crucial for the development and future use of land. Changes in land use may mean that established neighbouring users experience adverse impacts and interference directly caused by such changes. There is the potential, therefore, for nuisances to result directly from development and

changes of use. In *Allen v Gulf Oil Refinery Ltd*[110] the Court of Appeal affirmed two fundamental principles:

(1) a planning authority has no jurisdiction to authorise a nuisance; and
(2) the grant of planning permission can change of character of a neighbourhood.

The way tension between these two principles is reconciled is crucial for deciding what role Statutory Nuisance has when planning permission authorises an activity which causes adverse impacts and interference. In *Gillingham BC v Medway Dock Co Ltd*[111] the redevelopment of Chatham Naval Dock to a 24/7 container port changed the whole character of the neighbourhood. The planning permission therefore set a high threshold for disturbance to be regarded as a nuisance in the context of the changed neighbourhood; and disturbance to residents could not be avoided by the newly authorised use. The economic realities of change prevailed, and the scale of the change resulting from the grant of planning permission meant that claims in nuisance based on the previous character of the neighbourhood could not be sustained.

The two principles cited in the Gulf Oil case were reconciled by Buckley J in *Gillingham* thus:

"In short, where planning consent is given for a development or change of use, the question of Nuisance will thereafter fall to be decided by reference to a neighbourhood with that development or use and not as it was previously".

After the *Gillingham* case, it appeared until *Wheeler v JJ Saunders Ltd*[112] that nuisance was subordinated to, even subsumed by, planning legislation. The crucial difference between these cases was over the scale of change. Wheeler did not involve change in the whole character of a neighbourhood, even though the defendants had argued that there had been intensification in the use of the land. The facts of this case were that a nuisance resulting from the housing of 800 pigs within a distance of 36 feet of the plaintiff's holiday cottages caused a substantial interference in the enjoyment of that land. The extension of the pig farm did not amount to an intensification of use significant enough to indicate a change in the character of the neighbourhood whereby the matters complained of would not be regarded as a nuisance.

Since *Wheeler* the position has been that where the scale of development resulting from the grant of planning permission is such as to change the nature and character of a neighbourhood, then, provided that reasonable steps are taken to minimise annoyance and inconvenience; the threshold for nuisance is raised to accommodate the change i.e. what may have amounted to a nuisance prior to development that

[110] *Allen -v- Gulf Oil Refining Ltd [1981] AC 1001; [1980] UKHL 9*
[111] *Gillingham* v *Medway Chatham Dock Co Ltd* [1992] 2 WLR 449
[112] *Wheeler* v *JJ Saunders Ltd* (Court of Appeal, 19 December 1994; *The Times*, 3 January 1995);

changes the nature and character of a neighbourhood; may not be a nuisance after such a development. This threshold may go down as well as up, for example where a locality previously used for commercial purposes is regenerated for residential use. Where a change is less substantial and there has not been a change in character, the standard for deciding whether a nuisance exists remains the same.

More recently than the *Gillingham* and *Wheeler* decisions is the case in the Supreme Court of judicature Court of Appeal (civil division) of *Watson Vs Croft Promo Sport [2009] EWCA Civ 15*. This case concerned noise nuisance from the use of a disused airfield for motorsport; and amongst several issues it considered if the planning permission for motor sport use authorised any resulting nuisance. At paragraph 32 of the judgement the Chancellor of the High Court, Lord Justice Richards rejected the proposal that planning permission can authorise resulting nuisance with the following words:

"I would reject this submission for a number of reasons. First, it is well established that the grant of planning permission as such does not affect the private law rights of third parties. This was clearly stated by Cumming-Bruce LJ in Allen v Gulf Oil Refinery [1980] QB 156, 174G-H and has been consistently applied in all the subsequent cases, see per Buckley J in Gillingham Council v Medway Dock Co.[1993] QB 343, 359, all three members of the Court of Appeal in Wheeler v JJ Saunders Ltd [1996] Ch. 19, 28A-H, 30C-D, 34G-H and 38B, Pill LJ in Hunter v Canary Wharf Ltd [1997] AC 655, 669A-B and the speech of Lord Cooke of Thorndon on appeal at page 722F-G. Second, the implementation of that planning permission may so alter the nature and character of the locality as to shift the standard of reasonable user which governs the question of nuisance or not. This too is clearly recognised in the judgments of Staughton and Peter Gibson LJJ in Wheeler v JJ Saunders Ltd [1996] Ch. 19, 30D-E and 35G and the speech of Lord Cooke of Thorndon in Hunter v Canary Wharf Ltd [1997] AC 655, 722G."

The *Watson* case also decided that the implementation of planning permissions which permitted motor racing at the former aerodrome had not altered the nature and character of the locality which was essentially rural. This was because the consequence of the planning permissions was not to introduce an element of noise which qualified the essentially rural character of the locality. However, whilst the implementation of planning permission might so alter the nature and character of the locality as to shift the standard of reasonable user which governed the question of nuisance or not, *Wheeler v JJ Saunders Ltd (1996) Ch 19 CA (Civ Div) and Hunter v Canary Wharf Ltd (1997) AC 655 HL* considered. In the light of those two well established principles there could not be any middle category of planning permission which, without implementation, was capable of affecting private rights. In any event, even if there were some middle category such as that for which the defendant contended, the grants of permission in these cases were not strategic decisions affected by considerations of public interest, *Wheeler* and *Hunter* considered. Any relevant change in the nature and character of the locality must have arisen from the implementation of the grants not their mere existence. But neither the tortious activities of a defendant nor the intensification of a particular use could change the essential character of the locality, *Dennis v Ministry of Defence (2003) EWHC 793 (QB), (2003) Env LR 34* and *Wheeler* considered. Whether there

had been a change in the nature and character of the locality was a question of fact and degree; and in this case there had been no such change capable of rendering the noise from the motor sport reasonable in the context of the nature and character of the locality.

ETSU-R-97 states that "*The suggested noise limits and their reasonableness have been evaluated with regard to regulating the development of wind energy in the public interest*."; rather than with a view towards protection of the private law rights of third parties not to suffer Statutory Nuisance. Consequently, compliance with the guidance of ETSU-R-97 does not provide an automatic defence or exemption against Statutory Nuisance action, except where doing so means the normal tests for statutory nuisance are satisfied; because the ETSU-R-97 guidance favours the public interest rather than private rights. The conflict between public interest and private rights was considered in the civil nuisance case of *Dennis v Ministry of Defence [2003] EWHC 793* referred to above*,* where Buckley J found in favour of Mr and Mrs Dennis whose home and estate was seriously affected by high levels of noise from the operation of RAF Harrier jets from the nearby base at RAF Wittering. The judge found the impact of the noise was a very serious interference with the enjoyment of their property. Having found it was a substantial interference with the enjoyment of the property, Buckley J considered whether it could be justified - in particular on the ground of public interest. In his decision he rejected the submission that the noise had become a prescriptive right or that public interest overrode private rights[113]. The public interest was reflected in the decision not to award any injunction restraining future behaviour. Instead, Buckley J made an award of damages of £950,000, which covered losses up to 2012 (when Harrier training was expected to end).

Applying the case law discussed above to wind farm development, it is clear that complying with planning permission does not provide an automatic defence against Statutory Nuisance action; although it seems likely that larger-scale commercial wind farm operations (not just those sufficient to be an NSIP) could come within the principles set down in the *Gillingham* case whereby the nature and character of a neighbourhood could be sufficiently changed following the implementation of planning permission; so that matters which might previously have been considered a nuisance are no longer so. However, smaller scale "micro-turbine" based schemes are unlikely to sufficiently change the character of a neighbourhood on their own (although any substantive development they are associated with might) so that nuisance is not caused. There is no prescriptive formula or mechanism that can be used to assess changes in the nature and character of an area, as what comprises a relevant change of character in a particular case is important and specific to the particular case. The environmental problems that resulted after the grant of planning permission in cases such as *Gillingham* and *Wheeler* were substantial. It may be that noise Statutory Nuisance arising from the operation of a wind farm is an indication that something seriously wrong had occurred in the planning process, such as inadequate noise impact assessment, poorly drafted conditions having been attached to the permission or the final scheme not matching what was permitted; there may have been faults in the design of the plant, or operational difficulties may be

[113] Although it is clear that if Parliament specifically authorises nuisance, the public interest can defeat private rights e.g. section 122 of the Railways Act 1993, prohibits nuisance actions against railway operators in relation to operational noise.

responsible for the Statutory Nuisance. Circumstances such as these could indicate that all reasonably practicable steps had not been taken to minimise annoyance and inconvenience, in which case recourse to a *Gillingham* defence could be problematic.

Whilst there has not been a case in the Higher Courts, the issue of a wind farm development changing the nature and character of a location sufficiently so that the noise from the scheme was not a Statutory Nuisance was considered by a District judge in the EPA'90 section 82 case of *Nichols, Albion and Lainson v. Powergen Renewables Limited and Wind Prospect Limited (South Lakeland Magistrates' Court, 20 January 2004)*. In defence it was submitted, on the basis of the *Gillingham* case, that the grant of permission for a wind farm had changed the character of the area, and thus altered what could be reasonably expected by way of noise. The former planning officer of the Council, called as a witness by the residents, accepted in cross-examination that the permission had changed the character of the locality from purely rural and agricultural, to an area with industrial characteristics. Whilst this specific case does not set precedent (as it's the judgment of a District Judge sitting in the magistrates court) it is grounded in the basic common law principles of nuisance which include consideration of what is reasonable in the context of the locality and the specific considerations of the *Gillingham* and subsequent *Wheeler, Dennis* and *Watson* cases.

In conclusion, it would seem that circumstances could arise when use of Statutory Nuisance powers might be deemed inappropriate because of the availability of a *Gillingham* defence. But making such a decision would require attention to the particular circumstances and careful analysis of all the relevant factors as per the *Wheeler, Dennis* and *Watson* cases.

4.17 Complying with Planning Permission and the Prejudicial to Health Limb of Statutory Nuisance

The possibility of running a *Gillingham* defence only applies to the nuisance limb of Statutory Nuisance under section 79 of the EPA 1990. Where injury to health is an issue, this cannot be justified by the grant of planning permission changing the character of an area. It would be possible to serve an abatement notice under section 80 of the EPA where, if following the grant of planning permission, injury to health (or the threat of injury to health) resulted from the development. An abatement notice doesn't have to identify which or if both limbs of Statutory Nuisance apply, simply that the matter amounts to a Statutory Nuisance.

4.18 Statutory Authority

Statutory authority can provide a defence to activities which would otherwise be a Nuisance. It applies in particular circumstances especially when the public benefit of the permitted activity is great and the resulting level of Nuisance is proportionately small. There are certain kinds of noise, such as aircraft, road traffic and railway noise, for which specific legislative provisions apply that, can either exclude or provide a defence against action or prosecution in nuisance, including Statutory Nuisance.

At the time of writing, in England and Wales statutory authority providing a defence to civil or criminal forms of nuisance will apply in respect of energy generation facilities above a certain size, including wind farms designated as nationally significant infrastructure projects (NSIP) under section 158 of the Planning Act 2008. However, the statutory authority defence available under the Act does not provide immunity from prosecution for Statutory Nuisance or public nuisance e.g. it doesn't mean the complaints should not be investigated or abatement notices should not be served. Nor does it provide complete immunity from civil actions in nuisance. Where the developer or operator is shown to be negligent, this can mitigate the defence of statutory authority and open the way to obtaining tort based remedies. Furthermore, the IPC or whoever will be responsible for setting conditions for the development will have the discretion to limit the scope of the statutory authority. It will consider each application for an authorisation on its merits and thus has the power to remove the statutory authority in respect of civil or criminal forms of nuisance at the authorisation stage. Whether these decision makers will choose to use such powers to limit the scope of statutory authority in this way remains to be seen.

4.19 Legal Requirements and the Role of Enforcement Officers

The provisions of the EPA'90 concerning noise nuisance are not intended to provide a comprehensive regime to control noise pollution or play an active part in improving the general noise climate in which people live and work. The provisions of the EPA'90 are concerned with the extent that noise emitted from a specific source interferes with the ordinary use of property or personal comfort, and/or health, which are questions of fact for the court to decide. The threshold is a high one: Statutory Nuisance action has never been intended for what might be termed as '*mere annoyances'*, or to protect amenity to the same extent as can normally be achieved via planning permission.

The Local Authority has to form an opinion, that is, make a decision about whether a matter or complaint amounts to a nuisance or is prejudicial to health before serving an abatement notice under section 80 of the EPA'90. In practice, councils will rely on the professional opinion of environmental health practitioners (EHP) before coming to a decision[114]. The scope for challenging the opinions of EHPs as to noise nuisance is considerable, particularly in respect of industrial, trade or business premises, where a 'best practicable means' (BPM) defence is available. In reaching a decision Local authorities will need to consider the sufficiency and quality of evidence carefully, both that supporting the officer's opinion in a particular case and that from any lay witnesses to the Statutory Nuisance.

When complying with the legal duty to take reasonable steps to investigate complaints LAs may need to consider whether to obtain expert advice on noise levels and on any abatement measures that may be required. The local authority will also need to bear in mind that the person or company who is likely to be

[114] Relatively recently planning conditions for many larger wind farms have started to include conditions which require: following a complaint to the LA alleging noise disturbance at a dwelling, the wind farm operator to, employ, at their expense, a consultant approved by the Local Planning Authority, to assess the level of noise immisions from the wind farm at the complainants property. However, the evidence gathered by such a condition, if the developer complies, may not be admissible in a Statutory Nuisance case as there is no PACE '86 caution and there are issues in regard to data protection and the purpose for which a wind farm operator is required to submit such information; additionally reliance on this condition does not comply with the requirement of the EPA '90 for LAs to take reasonable steps to investigate complaints.

served with an abatement notice (or the defendant in a prosecution for breach of a notice) is entitled to rely on expert evidence in bringing an appeal; and cases can be substantially weakened where expert evidence from one party is not countered by equivalent but contrary expert evidence or interpretation by the other side. Although there is no legal requirement for EHPs to take noise measurements before making a decision about noise nuisance; because it is common for any appellant or defendant who contest whether nuisance is occurring or who invoke a BPM defence, to include noise measurements as part of their case. Local Authorities should be prepared to provide clear reasons for deciding not to obtain scientific noise measurements if required to justify their decision to do so at appeal or during a prosecution. The absence of expert evidence and lack of noise measurements on behalf of the losing plaintiff was a factor in the Magistrates Court dismissing the action against the wind farm operator in the case of *Nichols, Albion and Lainson v. Powergen Renewables Limited and Wind Prospect Limited (South Lakeland Magistrates' Court, 20 January 2004)*; whereas the successful defendant relied heavily on expert and noise measurement evidence in their defence.

The approach adopted by the Local Authority to control noise problems can include advice and persuasion rather than proceeding straight to prosecution. Balancing this, however, is a statutory duty to serve an abatement notice under section 80 of the EPA '90 once the point has been reached that the Local Authority is satisfied that a Statutory Nuisance exists, or is likely to occur or recur. There is no legal duty to consult with noise producers, though there may be good practical reasons to do so, as a recipient of a notice would usually find it hard to justify an appeal if they have contributed to the contents. All this requires a great deal of professionalism, knowledge and time. Under-enforcement fails to protect the public and produces the risk that those affected by noise will complain to the local government ombudsman; over-enforcement may result in damage to the local economy, expose the regulator to the risk of losing appeals in the magistrates' courts and is unfair to the businesses concerned. In this regard local authorities have a difficult task and should take care to plan their approach carefully, and to record in detail the reasons for proceeding in a particular manner at each stage in the process.

4.20 Establishing Liability for Statutory Noise Nuisance

The legal requirements for establishing liability in Statutory Nuisance cases are objective. The thresholds is a high one: either material interference with use of property or personal discomfort or injury to health must be proved in England, Wales and Northern Ireland or the matter must be more than is ordinarily tolerable or injurious to health in Scotland. The standard cannot be defined precisely; each case should be examined on its merits; and where there is a dispute much will depend on the view taken by the court of the seriousness of the harm.

Reaching a decision whether a complaint amounts to a Statutory Nuisance often requires that a number of factors need to be weighed up and assessed properly. Frequently, issues are not clear cut, so care and professionalism are needed if decisions are to be made both properly and fairly. The relevant factors are detailed in many precedent setting cases and legal texts, but include:

- the level and type of noise;
- duration and how often the noise occurs;
- the time of day or night when the noise occurs;
- whether any aggravating characteristics are present in the noise;
- what measures could reduce or modify the noise;
- the characteristics of the neighbourhood where the noise occurs;
- sensitivity of the complainant;
- motive of the person responsible.

The Local Authority must take an independent and objective view of the situation and not be over-influenced by the persuasiveness of either noise producers or complainants.

Statutory Nuisance cases differ from those brought in private nuisance because it is the opinion of the local authority as set down in the abatement notice which defines the boundary of the nuisance. Crucial in establishing the reasonableness of that opinion is the quality of the evidence employed to justify service of the abatement notice. Evidence that will assist the court includes complainants' noise diaries, reported effects, subjective observations, meteorological monitoring and noise monitoring. Any monitoring should be overseen by competent persons employed by the local authority, although staff from other local authorities or external consultants and specialists can be used under supervision by the competent persons employed by the Local Authority. A contemporaneous note made by officers of the extent and type of noise they witness will also be relevant. The standard of proof required to serve a notice is the civil standard: on the balance of probabilities; whereas the standard for prosecution for non-compliance with an abatement notice is criminal i.e. beyond reasonable doubt.

4.21 Drafting Noise Abatement Notices under the EPA 1990

The Local Authority has a broad discretion about which type of notice to serve: either a specific works or steps notice or a simple abatement notice. Section 80(1) EPA 1990 stipulates that the abatement notice should include all or any of the following requirements—(a) requiring the abatement of the nuisance or prohibiting or restricting its occurrence or recurrence; (b) requiring the execution of such works, and the taking of such other steps, as may be necessary for any of those purposes

Where a Local Authority chooses to specify works or steps, they must be sufficiently specified so as to make it clear precisely what the recipient must do to conform to the requirements; as it is the carrying out of these works or steps which is required for compliance with the abatement notice. Alternatively, a Local Authority can serve a simple abate the nuisance notice without specifying works, leaving it up to the recipient to decide how to abate the nuisance. The Local Authority can decide not to suspend such a notice pending an appeal, in so far as allowed by the Statutory Nuisance Appeal Regulations.

The case of Sevenoaks DC VS Brands Hatch Leisure Group Ltd [2001] Env LR 86[115] has established that stipulating noise limits in an abatement notice and specifying how monitoring should be undertaken do not constitute 'steps' under section 80(1) of the EPA 1990. Therefore, a simple notice served in the section 80(1)(a) form which specifies noise limits in the body of the notice will be appropriate in some cases, especially when the abatement of the Statutory Nuisance involves little more than turning down the source noise levels, as occurs in many entertainment noise cases. A simple notice may be appropriate in a wind farm case, if, for example, the choice of remedial action is simple as might be the case where the noise problem results from poor plant maintenance or can be remedied by managing rotor speed; or where the local authority wish to allow the operator to use their discretion and expertise in order to abate or adequately restrict the Statutory Nuisance.

By comparison, serving a simple abatement notice in a wind farm case where the level of noise is higher than was anticipated at the planning stage may be considered unhelpful; although lawful. In a complex scenario where the solution is unclear, it would be better practice to try and formulate a specific and agreed form of notice with the company operating the plant. Such a notice is less likely to be appealed than a simple notice which fails to define the boundary of the nuisance. As ever, each case needs to be considered according to its particular facts. It should also be remembered that in these circumstances it is likely that the planning conditions may also be breached. In which case the LA should simultaneously follow Planning and Statutory Nuisance procedures separately, including serving breach of condition and abatement notices (as neither is the start of a criminal action); up to the point that that LA might lay information for criminal proceedings for the crime of not complying with either the breach of condition or abatement notices. At which point the LA should decide which criminal course of action to follow through with and which to abandon in order to avoid counter claims of "*double jeopardy*".

But, as shown by the *Elvington*[116] case, an appeal against a simple notice, even in a complex case where there is no known solution to a noise problem, is unlikely to succeed on grounds of irrationality. Although a Local Authority cannot be obliged to serve an abatement notice specifying steps to be taken or works to be carried out, even where invited to do so by the recipient, it should still consider what type of notice to serve and make its decision properly and record the reasons for later justification if required. It is considered for a Local Authority to formulate a policy only to serve simple notices and to eschew specific works notices would be to limit its discretion in each case and would therefore be *ultra vires*. As ever in

[115] Sevenoaks DC VS Brands Hatch Leisure Group Ltd [2001] Env LR 86…6.75 - It was inherent that every abatement notice would require some steps to be taken in order for a notice to be complied with. Section 80(1)(b) of the Act only applied when a local authority chose to specify how the abatement was to be achieved. The council had identified the level of noise that would be acceptable and specified how that level of noise was to be ascertained. However, the notice served by the council had not actually or purportedly required any works to be carried out and accordingly it did not fall within s.80(1)(b) of the Act. The schedule had only given particulars of requirements to abate the Nuisance. The contention of the respondent that because the word "steps" had been used in the notice, it was invalid for not specifying those "steps", was hopelessly mechanistic. It was obvious what the notice required and it had caused no unfairness to the recipient. Accordingly, the notice served by the council had been lawful.

[116] *Elvington Park Limited & Elvington Events Limited v City of York Council [2009] EWHC 1805 (admin)* – a notice that required steps to be taken to abate a nuisance, but did not stipulate those steps; was not irrational, but was void because it did not stipulate those steps.

these matters the decision whether to serve simple “abate the nuisances” notices or specific works notices is best made on a case by case basis

Given the line of entertainment / leisure activities cases involving noise disturbance culminating in *Elvington*, the local authority’s discretion as to which type of notice to serve is very wide, with a correspondingly very limited scope to appeal on the ground that the authority should have served a specific works form of notice. It is good practice, however, for the Local Authority to seek to be fair both to the complainant and to the noise producer.

A choice of remedies frequently applies in entertainment and domestic noise cases where it will often be possible to stop causing the nuisance by turning down the noise source or by not holding the event. In the notice served by the Local Authority in *SFI Group plc (formerly Surrey Free Inns plc) v Gosport BC* it was stated that the recipient was required ‘*to cease the playing of amplified music at levels which cause a nuisance at neighbouring premises*’. The choice of how to comply with the notice was left to the noise producer: it could cease playing the music, keep the volume down, or undertake works to prevent the noise from leaving the premises. The validity of the notice was upheld by the Court of Appeal. This type of noise scenario is not likely to be relevant in an industrial noise situation, such as a wind farm, where a technically difficult and possibly expensive solution may be required for dealing with a problem. Sometimes there appears to be no solution capable of bringing the noise problem down to below the nuisance threshold short of restricting plant, plant closure or curtailing its hours of operation. Where the Statutory Nuisance regime is being used, in effect, to constrain the plant this may be found inappropriate by the court, in which case the “Best Practicable Means” ground for appeal or defence against enforcement of the abatement notice can be used to enable the wind farm to continue to operate, albeit probably in a modified mode whereby the Statutory Nuisance is restricted rather than subject to full abatement.

4.22 Noise Emitted from Industrial, Trade and Business Premises

The situation might arise when the company has already taken ameliorative measures but the Nuisance remains. When this happens two questions can arise. Firstly, should a local authority serve a notice; the answer to which is yes as they have statutory duty to do so[117]. Secondly, if so, what form should the abatement notice take? Whilst not strictly illegal, it is unlikely that it would be helpful to serve a simple abatement notice in this situation, though the authority would be entitled to do so. This is either because the effect of a simple notice would be to stop the process operating at the premises, or because it is not practicable to reduce the noise emanating from the premises any further. Therefore a simple and unfocussed abatement notice served in this situation would not assist in resolving the problem. In this case a hybrid notice as in the Brands Hatch Vs Sevenoaks case referred to above specifying noise limits but making no reference to “steps” or “works” could be more useful.

[117] Section 80, pt 1 EPA’90 and R v. Carrick District Council ex parte Shelley [1996] Env.L.R. 273

A possible further question arises over the reasonableness of the use of land, particularly where the premises are being operated in accordance with planning permission. It was held in the common law nuisance case of Cambridge Water Co. v Eastern Counties Leather plc[118] that where the '*user is reasonable, the defendant will not be liable for consequent harm to his neighbour's enjoyment of land*'. Translating this to a Statutory Nuisance scenario, if the user is found to be reasonable then there is no nuisance and an abatement notice is not justified; unless the prejudicial to health limb is also triggered as reasonable use is not relevant to this limb of Statutory Nuisance. However as discussed earlier the granting of planning permission does not authorise any or all Statutory Nuisance that might arise as a result of the permitted use of the land and as the question of reasonable use includes considering the potential impacts on neighbouring land owners and users this is unlikely to be a strong defence.

It could be argued that wind turbine noise is different from some other types of noise (notably entertainment and domestic noise) because it provides significant environmental and social as well as economic benefits[119]. Service of a simple abatement notice that did not take into account these benefits might also be seen as a crude attempt to regulate the problem. Although the regulator has a discretion to serve a simple abatement notice in these circumstances, that does not justify using such discretion unwisely. However, in the light of the *Elvington* decision and the absence of specific guidance from the courts as to when it would be "*irrational*"[120] to use a simple abatement notice, it can be argued that the courts would be reluctant to punish erroneous use of such discretion where the decision to do so was made in good faith; although the Local Authority can legitimately be required to justify their decision at appeal.

4.23 The Defence of Best Practicable Means (BPM) in Noise Cases

The Environmental Protection Act 1990 provides for the concept of "best practicable means" to be used as a ground for appealing an abatement notice and/or a defence against prosecution for not complying with an abatement notice. BPM is defined in Part 9 of section 79 of Environmental Protection Act 1990 as follows:

''*In this Part "best practicable means" is to be interpreted by reference to the following provisions —*

(a) "practicable" means reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications;

[118] *Cambridge Water Co Ltd v Eastern Counties Leather plc [1994] 1 All ER 53*

[119] i.e. they produce electricity without adding to climate change gases and therefore contribute to mitigating climate change impacts on local, regional, national and global basis.

[120] Lord Justice Simon Brown in *R v Falmouth & Truro Port Health Authority, ex parte South West Water ltd (2000*); LTL 30/3/2000 : (2001) QB 445 : (2000) 3 WLR 1464 : (2000) 3 All ER 306 : (2000) Env LR 658 : (2000) EG 50 (CS) : (2000) NPC 36 : Times, April 24, 2000

(b) the means to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery, and the design, construction and maintenance of buildings and structures;
(c) the test is to apply only so far as compatible with any duty imposed by law;
(d) the test is to apply only so far as compatible with safety and safe working conditions, and with the exigencies of any emergency or unforeseeable circumstances;''

Local authorities are best avoiding interpreting their duty under Part III EPA 1990 as a means of obliging businesses to go beyond the abatement of Statutory Nuisance. LAs have no powers to require the most expensive, best available, or 'state of the art' technology to reduce noise problems to a minimum[121]. The requirement is that enough is done to prevent or (as far as practicable) counteract the effects of the nuisance.

Normally compliance with a statutory or industry recognised code of practice or standard of operation is a significant indicator that BPM is being used to counteract the effects of noise; as this can be regarded as a statement of "*current technical knowledge*". However, this is unlikely to apply where the code of practice or standard of operation applied is not up to date or doesn't take account of the latest advances in the scientific understanding of the adverse impacts of the industry i.e. it is not current.

When using BPM as a ground for appeal or defence against enforcement of an abatement notice it is explicit that the matter identified is recognised by the appellant or defendant as a nuisance i.e. it is not a factor to be considered in judging Statutory Nuisance, but is relevant to deciding what can be required of the person responsible. This point is firmly made in the recent High Court decision in the Judicial review case of *R (on the application of South Kesteven District Council) (claimant) v Grantham Magistrates' Court (defendant) & (1) Kevin Bartholomew (2) Marcella Tomlinson (Interested Parties) (2010] EWHC 1419 (Admin) QBD (Admin) 11/5/2010*; where at paragraph 19, Mr Justice Wyn Williams states in regard to the statutory defence of BPM that:

"*it seems to me that the statutory defence arises only if a noise nuisance is established. The offence is failing to comply with the abatement notice; there is no failure to comply with the abatement notice if no statutory nuisance exists. Accordingly, to repeat, the statutory defence arises only after an acceptance or proof of breach of the abatement notice*"

The concept of BPM provides a mechanism to protect commercial interests when Statutory Nuisance arises and sometimes can result in allowing a Statutory Nuisance to continue. The origins of the defence were to prevent such interference in the activities of the manufacturing and business classes as would have harmful economic consequences[122] and some of this philosophy still applies, as illustrated in the

[121] *Welton v North Cornwall DC [1997] 1 WLR 570.*
[122] *See R. Malcolm & J. Pointing, Statutory Nuisance: Law & Practice (2002: OUP) chapter 3, for an historical analysis of nuisances.*

case of *Manley v New Forest DC*[123]. This case concerned the commercial keeper of a pack of Siberian huskies, who had a licence going back many years allowing the dogs to be kennelled in a mixed residential/ commercial area. The problem arose from the howling of the pack. The Divisional Court accepted the findings of the Crown Court (on appeal from the magistrates' decision) that although Statutory Nuisance was proven noise abatement measures, such as glazing the kennels, would not be a practicable solution. However, it rejected the judge's finding that BPM requirements would be satisfied if the kennels were relocated elsewhere – this being considered too onerous a requirement to impose upon a legitimate business. The Divisional Court accepted that the nuisance would continue but that it was not actionable as a statutory nuisance[124]. The decision in *Manley v New Forest DC* confirms that great care is needed before serving a notice in noise cases where the BPM defence is available.

Best Practicable Means (BPM) is a statutory defence (EPA'90 section 80, pt 7) so it is for the appellant/defendant to make out the defence[125], and it is for the court to decide whether it has been correctly made. It can be raised at two stages: when appealing against the service of an abatement notice or as a defence in a prosecution brought for breach of the notice. In either case, it will be up to the noise producer to prove, to a civil standard, that BPM have been used to prevent or to counteract the effects of the nuisance. This defence is limited by section 80(8)(a) of the EPA 1990 to noise emitted from 'industrial, trade and business premises.'

Having established a noise problem amounts to a Statutory Nuisance, the local authority will need to consider whether reasonably practicable steps have been taken to mitigate it in framing the requirements of any abatement notice. Practitioners should note that the BPM requirements under the EPA'90 include '*counteracting the effects*' of the noise, so full abatement is not the test. Furthermore, where the person or company is suggesting alternative, or less expensive, ways to deal with the problem, the local authority will be under a duty to consider them as it is a specific ground for appeal of the abatement notice not to do so. Should these be sufficient to mitigate a Statutory Nuisance from occurring or recurring then it would be unreasonable for the local authority to insist on more comprehensive measures being taken.

Expert advice may be needed to help decide whether a Statutory Nuisance has been caused, and, if so, to determine the form of notice the authority should serve on the noise producer.

Besides constituting good practice in drafting the requirements of an abatement notice, there is nothing set down in the EPA'90 to require the local authority to consider BPM before service of the notice. BPM

[123] *Manley and Manley v New Forest DC [1999] 4 PLR 36.*

[124] This judgment also implies that the requirements needed to prove a statutory nuisance may be higher than for common law nuisance, whether private or public. In the words of Newman J (at 41):
'…it is …important to remember the distinctive legal actions or processes available in connection with the law of nuisance. There are distinctive aspects of the law of nuisance: private nuisance, public nuisance and now, as one sees in this Act, statutory nuisance. Proof of private or public nuisance will generally lead to the cessation of the nuisance, but the provisions of the 1990 Act are penal and they give rise to criminal proceedings in the event that a notice is not complied with. They affect the way in which a permitted lawful business is being carried on. Parliament plainly thought it right to give the operator of a business the benefit of the principle of "best practicable means", otherwise, in my judgment, it would be obvious that great hardship could be caused to businesses …'

[125] As per the Magistrates Court Act 1980, s101.

was considered in the drafting an abatement order in a Crown Court appeal against the magistrates' decision, in an action brought under section 82 of the EPA '90, in the Alton Towers case[126] where the High Court upheld the Crown Court's decision that commercial considerations had been relevant in deciding on the proportionate degree of abatement or restriction of the nuisance; but not in regards to whether nuisance was being caused. In this case whilst the High Court firmly rejected the argument that consideration of BPM by the local authority only became relevant where there had been a breach of an abatement order; it clearly did not state that BPM or commercial considerations were relevant to deciding whether the matter complained of was a Statutory Nuisance. Indeed in providing answers to the questions raised in the Roper case Mr Justice Wilkie stated the following:

"*The court was obliged to have to regard to all relevant circumstances which included commercial considerations provided it performed its statutory duty of making an order which abated the statutory nuisance*"[127].

Consideration of BPM by the local authority when deciding on the framing of any abatement notice is a delicate area, since an element of consultation may be required before the local authority can satisfy itself whether BPM have been used to mitigate the Statutory Nuisance sufficiently, or whether any further steps are required. There is no requirement in the EPA'90 or in any regulations to consult in Statutory Nuisance cases. Indeed, the Court of Appeal has warned that if local authorities choose to consult with potential notice recipients they risk creating a legitimate expectation that such consultation will be comprehensive[128]. Councils who wish to avoid raising such an expectation should limit their requirements for information about BPM and make it clear that they are not engaging in a consultation exercise on wider issues such as whether the noise amounts to a Statutory Nuisance.

A particular difficulty arises when the noise producer has taken all reasonable steps to reduce the level of noise, but the problem remains a Statutory Nuisance in the eyes of the local authority. The extent of the Statutory Nuisance may have been diminished by steps taken by the noise producer and the noise may only marginally constitute a Statutory Nuisance. This situation seems to be rarely litigated, maybe because companies and local authorities usually cooperate to find a solution which avoids expensive and time-consuming litigation. The opinion of the local authority as to whether there is, or continues to be, a Statutory Nuisance cannot always be precise. It may need reviewing in the light of changing circumstances or because further facts emerge. Statutory Nuisance is not conceptually precise and the local authority should appreciate that an opinion formed about a Statutory Nuisance, though objectively made, cannot always be based on a '*fine line*' distinction. What is essential is that local authorities have clearly in mind the reasons that justify and buttress their opinion whether a Statutory Nuisance exists, or is likely to occur or recur.

[126] Roper v Tussauds Theme Parks Ltd (2007) [2007] EWHC 624 (Admin)
[127] Paragraph 27, question 3.
[128] R v Falmouth & Truro PHA, ex parte South West Water Ltd (1989) Env LR 833,

4.24 Standard of Abatement

Local authorities need to avoid interpreting their duty under section 80 of the EPA 1990 as a way of obliging businesses to adopt too high a standard of abatement. They have no powers to require the most expensive, best available, or 'state of the art' technology to reduce noise problems to a minimum. The requirement is that enough is done to reduce the problem to below the nuisance threshold; or where the BPM defence applies to reasonably practicable measures to counter the effects of the nuisance.

4.25 A Framework for Utilising the Statutory Nuisance Regime to Regulate Noise from Wind Farms

Wind farm development constitutes a use of land with the potential to cause noise disturbance and provoke complaints about noise. Depending on the circumstances common law as well as Statutory Nuisance actions may be invoked. The use of the Statutory Nuisance regime to control noise nuisances pre-dates the construction of wind farms. Whilst the fit between the legislation and the potential problems arising from wind farm development is not simple and direct, the Statutory Nuisance regime has an important role to play in the regulation of some noise problems caused by wind farms.

Whether or not a Statutory Nuisance arises in particular circumstances will depend on the degree to which the usual tests considered when investigating Statutory Nuisance are satisfied.

A flow chart outlining the suggested steps for investigating complaints of Statutory Nuisance due to noise from wind farms is provided in Appendix C to this report.

4.26 Alternative Dispute Resolution

Alternative dispute resolution includes a range of practices from informal approaches or letters by Council staff to alleged noise makers to more structured arbitration and mediation methods. Alternative dispute resolution methods can be successful and may be quicker, cheaper and more effective in some cases where a noise dispute exists, than formal use of the Statutory Nuisance powers.

However, Local Authorities are reminded of their duties under sections 79 and 80 respectively of the Environmental Protection Act 1990 to take reasonable steps to investigate nuisance complaints and to serve abatement notices when satisfied of Statutory Nuisance. Consequently, where alternative dispute resolution methods are appropriate they should run in parallel with steps to comply with duties to investigate and take action against Statutory Nuisances. For example, this could be by holding enforcement of an abatement notice in abeyance whilst mediation was on-going or using any enforceable elements of the agreed outcome or action plan from mediation to form the basis of the requirements of an abatement notice.

Section 4.5 of the Defra/CIEH Neighbourhood Noise Policies and Practice for Local Authorities – a Management Guide[129] provides more information on alternative dispute resolution. Similar advice is provided in the Draft Scottish Noise Management Guide at section 4.11[130].

4.27 Summary and Suggestions

Developers and EHOs should engage with each other at as early a stage as possible in the development of a wind farm. Time spent early in the planning process in discussion of where? how? and for how long ? to measure background noise and how to use the guidance of ETSU- R- 97; can pay dividends in minimising the risk of problems once a scheme is operating

The provisions in the EPA '90 concerning Statutory Nuisance can be used to control and manage noise arising from wind farm development. However, the scope of noise problems that can be addressed using Statutory Nuisance methods can be limited and the standard of relief that can be achieved restricted by the statutory and legal precedents and conventions that apply. Ideally local authorities should utilise planning controls to manage noise from proposed wind farms as a first line of defence. Because, in general, and in line with most other forms of noise generating development, effective use of the planning system should prevent noise Statutory Nuisances from being emitted from wind farms. However, uncertainties in regard to the impact of noise from wind farms and the prediction and assessment of noise in general; mean that similar to many other forms of industrial development the planning system cannot guarantee that Statutory Nuisance from wind farm noise will not arise in all circumstances; only that the risk is managed to an acceptable degree. Although the degree to which the planning system can achieve this is restricted by the rigour with which it applied to a scheme and the ability of any standards applied in framing controls to adequately address foreseeable adverse impacts.

There are important limitations in taking Statutory Nuisance action e.g. the "BPM" defence, and the difference in the standards that can be achieved via the planning and statutory nuisance routes. It is vital, therefore, that planning conditions and agreements are put in place to adequately safeguard amenity and protect the rights of the neighbouring public from nuisances. Local Authorities should satisfy themselves that any noise assessments submitted with the planning application identify all the significant likely noise impacts, the measures to be taken to mitigate and control such impacts, that proper consideration is given to issues of scientific uncertainty and monitoring of impacts after the scheme becomes operational.

As described in section 4.16 the grant of planning permission does not authorise a nuisance. Statutory Nuisance action can be taken independent of planning requirements; but only in so far as the nuisance or the prejudice to health limbs of section 79 EPA 1990 can be invoked. When considered with the authorised grounds for appeal and defence against Statutory Nuisance actions, this can mean that the protection that can be secured under Statutory Nuisance is less than might normally be achievable using planning powers; and can vary significantly from one case to another.

[129] http://www.cieh.org/library/Knowledge/Environmental_protection/Noise/NoiseManagementGuideSeptember2006.pdf (last viewed 8th March 2011)
[130] http://www.scotland.gov.uk/Publications/2005/10/2192231/22317 (last viewed 8th March 2011)

5 Complaint Investigation Framework

Local Authorities have a duty to take reasonable steps to investigate noise complaints, and the standard of any investigation should be robust and scoped to reflect the circumstances and nature of the complaint so it is effective and capable of being defended in a subsequent court hearing or Ombudsman investigation. Local authorities must consider whether the noise complained of amounts to a Statutory Nuisance. They are under a duty to serve an abatement notice if satisfied that a Statutory Nuisance exists or is likely to occur or recur. When drafting the requirements of an abatement notice local authorities should also consider whether the BPM defence would be likely to succeed should an appeal be brought against the notice or used as a defence against prosecution for non-compliance.

The local authority should also consider the effectiveness of any alternative or less expensive ways of counteracting the noise suggested by the operator. It is good practice to discuss potential abatement measures with the operator of the wind farm, but care should be taken to avoid widening the scope and nature of any consultations by making it plain that the discussion is about the content of the notice; not whether to serve one or if Statutory Nuisance exists.

Whilst Local Authorities have the discretion to do so, they should be careful in deciding whether to serve a simple abatement notice or one specifying any works or steps that need to be undertaken in order to comply with the notice. It is recommended that where any works or steps are stipulated, they should be sufficiently specified so that the recipient of the notice has a clear understanding of what is required of them. Where an abatement notice gives particulars of the abatement required by means of specification of a noise level performance standard on an abatement notice it will be valid. The standard required should be sufficient to reduce the effects of the noise to just below the nuisance threshold relevant in the circumstances of the case; not to the lowest achievable or desirable standard.

5.1 Planning an Investigation

Taking reasonable steps to investigate noise complaints effectively can involve a high degree of fore thought and planning. Wind farms are no exception and investigation of noise complaints may need a sophisticated matrix of measures involving expenditure of significant time, staff and funding resources. Consequently, spending time at an early stage in planning an investigation of wind farm noise can pay dividends in maximising the efficiency of the investigation; and bolstering the robustness of any decisions made in regard to the existence of actionable Statutory Nuisance.

Key to scoping investigation of noise complaints is the need to make decisions in the context of the specific complaints made and the circumstances of each case. Consequently, there is no "*one size fits all*" approach that can be applied in all situations; instead a bespoke investigation is required in each case; although there will be certain common themes to each investigation, including those discussed below.

5.1.1 Formulating a planned investigation

5.1.1.1Reasonably practicable steps to investigate complaints

Local Authorities have duties under section 80 EPA 1990 to investigate Statutory Nuisance e.g.

- Firstly, the authority is under a duty to inspect its area from time to time in order to detect any statutory nuisances which ought to be dealt with.
- Secondly, where a complaint of an alleged statutory nuisance is made by a person living within its area, the local authority is under a duty to take such steps as are reasonably practicable to investigate the complaint.

Generally, in noise nuisance cases, it is the complaint route which triggers action by Local Authorities.

Good practice suggests that certain procedures in response to complaints do not comply with the legal duty to take reasonable steps to investigate complaints, as on their own they do not constitute an investigation in full. These include simply sending a warning letter to an alleged noise maker, or requiring complainants to fill in diary sheets, or of not responding unless more than one complaint is received from more than one complainant, with nothing more by the local authority..

Additionally failure to investigate or excessive delay in investigating out of hours noise due to staff shortages or lack of overtime funding has been found a breach of the duty to take reasonable steps to investigate complaints [131].

However, the duty to investigate is not absolute whereby every effort must be made to investigate at all costs and that an investigation must go on indefinitely, even without resolution being foreseeable. Instead, section 80 EPA' 90 only requires that "reasonably practicable" steps are taken to investigate complaints. Consequently, the duty to investigate may be mitigated by physical considerations e.g. the noise is too short in duration, irregular or infrequent for any Council staff to be able to witness or suitably record or measure; and what is reasonably affordable in terms of cost effectiveness and the proper use of Local Authority resources (See *Jordan Vs Norfolk CC 1994 4 All ER 218*).

In practice what are reasonably practicable steps to investigate each complaint will have to be judged on a case by case basis. However, carefully planning an investigation, and developing and recording an investigation action plan, which includes the reasons for the decisions made; will be helpful in focussing the investigation so its efficiency is maximised. These measures will also be useful in justifying the steps taken by the Local Authority as reasonably practicable if challenged by a complainant or the person responsible for any Statutory Nuisance; or if scrutinised by a third party decision maker e.g. the Courts or the Local Government Ombudsman.

5.1.2 Information from Complainants

In most circumstances the evidence gathered by Local Authority staff with suitable knowledge and skills will be used to establish whether Statutory Nuisance exists. As a consequence, the evidence collected will need to be robust and of good quality in case it is needed for any subsequent enforcement action by the local authority or at an appeal against any abatement notice. The best evidence is that witnessed and gathered first-hand by the LA staff or specialist consultants commissioned by the Local Authority, although reliable and corroborative evidence provided by a complainant will often be an important feature of an investigation, as the use of noise measurements can be. Therefore, it may be useful to confirm at an early stage of the investigation whether or not the complainants would be willing to attend court and to give evidence in support of any actions being contemplated by the local authority to address any noise

[131] *Local Ombudsman's Complaints 88/C/1571 and 88/C/182 against Rotherham Metropolitan Council, 26th November 1990, Commission for Local Administration*

problem arising from a wind farm operation; although any reluctance by residents to do this is not a suitable excuse for not carrying out reasonable steps to investigate a complaint.

Diary sheets can be a useful way for complainants to describe and record their own personal experiences of the noise; and these should be designed in such a way that all key information can be recorded. Their use will enable the incidence of reported interference from noise events to be correlated with meteorological conditions (primarily wind speed and direction) which may affect the noise emissions from the wind farm, which is useful in programming visits by LA staff during periods when the problem is most likely to occur. Diary sheets may also be used to corroborate evidence from investigating officer(s) or other witnesses on the occurrence or regularity of a noise. When diary sheets are issued, it is important to ensure that their purpose and the best method of completion are clearly explained to the complainant. Returned diary sheets should be date stamped and clearly marked with the file reference. Examples of a diary sheet and a noise time plot that can be derived from information recorded on the diary sheet are contained in Appendix 3, Note 3 of the Defra/CIEH Noise Management Guide[132].

Diary sheets kept by the complainant can form a useful part of the investigation. However, diary sheets on their own may not provide sufficient evidence of statutory nuisance or breach of a statutory notice, because:

- Diary sheets can be easily countered by simple claims that they are false, exaggerated and inaccurate or that the noise was from elsewhere.
- Diary sheets do not identify the person responsible for the nuisance.

The main usefulness of diary sheets lies in providing information to the enforcement officer so that judgements can be made on whether:

- is it worthwhile programming visits to maximise the probability of witnessing the noise, and if so when and for how long?
- is it likely that Environmental Health staff will ever witness the noise?
- the diary sheets could corroborate evidence from enforcement officers or other witnesses that the noise they have witnessed occurs frequently, at suitable times and/or for sufficiently long enough so as to constitute a Statutory Nuisance.

Again, it should be noted that a practice of issuing diary sheets and doing nothing else in response to a complaint, or not following up diary sheets once they have been issued does not comply with the Section 80 EPA'90 duty to take reasonable steps to investigate complaints of nuisance.

As well as asking complainants to complete diary sheets it can often be helpful as part of the investigation to interview complainants and gather more detailed information about the noise and how it affects them. For example by asking:

- The complainant to describe in their own words what the noise sounds like,
- Do they notice the noise more outdoors or indoors, or equally between outdoors and indoors?
- Does the noise only affect use of specific parts of their property, if so where?
- If there is more than one person in the household does in affect them equally or differently?
- What sort of activity does the noise interfere with? e.g. resting, sleeping, conversation, concentrating on work/reading, listening to TV/radio etc?
- Do they consider themselves normally sensitive to noise?
- Have they noticed a pattern to the noise? if so on what days and at which times do they find the noise is a problem?
- Can they estimate how long the noise tends to occur? or does it vary too much?
- Have they noticed the noise occurs or is worst under any specific weather conditions? e.g.

[132] See http://www.cieh.org/uploadedFiles/Core/Policy/Environmental_protection/Noise/NoiseManagementGuideSeptember2006.pdf (last Viewed 8th March 2011)

- When the wind blows from the turbine towards their home
- When the wind blows from their home towards the turbine
- When the wind speed is low
- When the wind speed is moderate
- When the wind speed high
- In warm conditions
- In cold conditions

5.1.2.1Information from Wind Farm Operator

A majority of wind farm operators may take their responsibilities seriously and cooperate positively in trying to resolve a complaint. Consequently, contacting the wind farm operator early in the investigation of the complaint can be useful in eliciting information; or even triggering their own investigation that may lead to a more rapid abatement of any nuisance so that an abatement notice is not required. Typically this has happened where the noise problem is due to a mechanical problem or limited to a single turbine which can be dealt with quickly and relatively easily, rather than any fundamental problem with the farm as a whole operating normally[133]. However, service of an abatement notice should not be unduly delayed by waiting for information to be provided by the wind farm operator.

5.2 Meteorological Data

The emission and propagation of noise from wind farms and equivalent immission levels at receptors are often strongly dependent on meteorological conditions. Consequently, detailed measurement and recording of the wind speed and direction, rainfall, temperature and relative humidity at the same location as, and simultaneously with, any noise observations or measurements are strongly recommended as part of the investigation. Mobile self-powered meteorological stations are readily available from environmental equipment sales and hire specialists.

Additionally it is likely to be valuable to consult the data submitted with the planning application for the scheme. This may include a wealth of information regarding prevailing and minority wind directions and speeds; and be useful to compare with any information from the complainant.

The University of Salford report NANR 233: Research into aerodynamic modulation of wind turbine noise, at section 4, pages 22 to 25[134] provides a description of an investigation that can be regarded as an illustrative example of how meteorological data can be correlated with information from complainants as a means of estimating when and how often problems are likely to occur. The figure below is taken from the Salford report and indicates how complaint information can be correlated with meteorological data e.g.

a. determine the range of wind speed and direction prevailing at times when complaints occur;

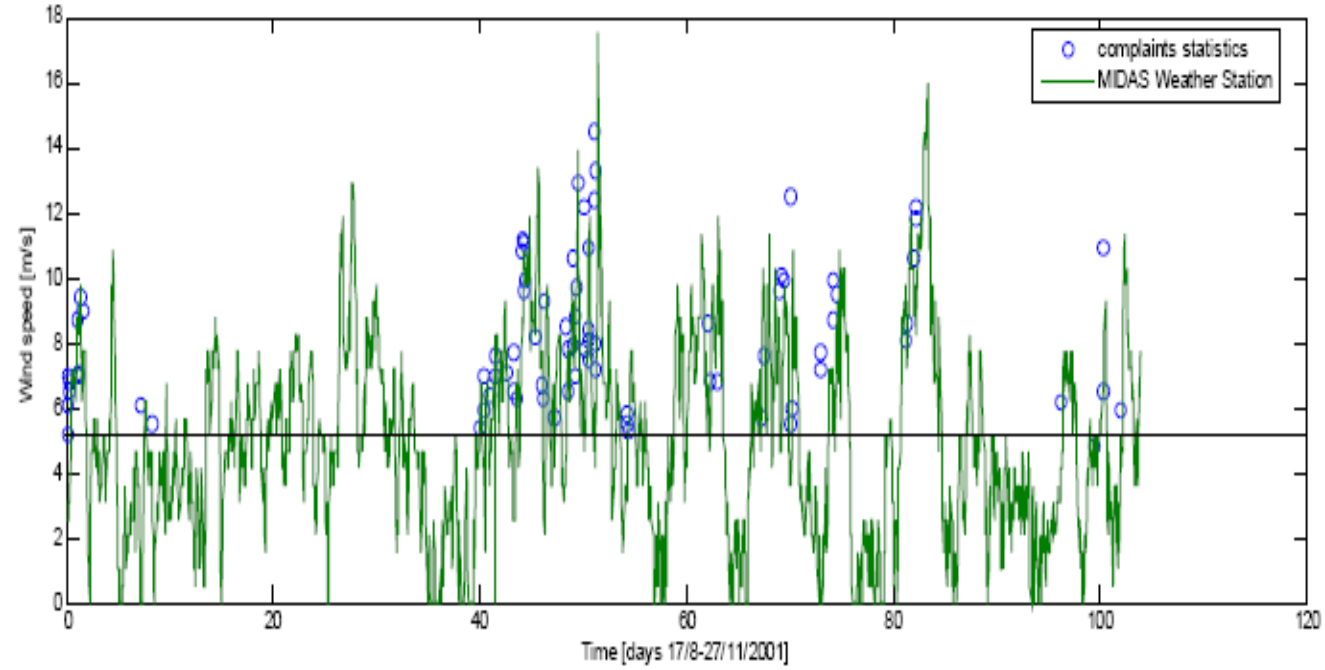
b. obtain continuous records of wind speed and direction occurring at the site;

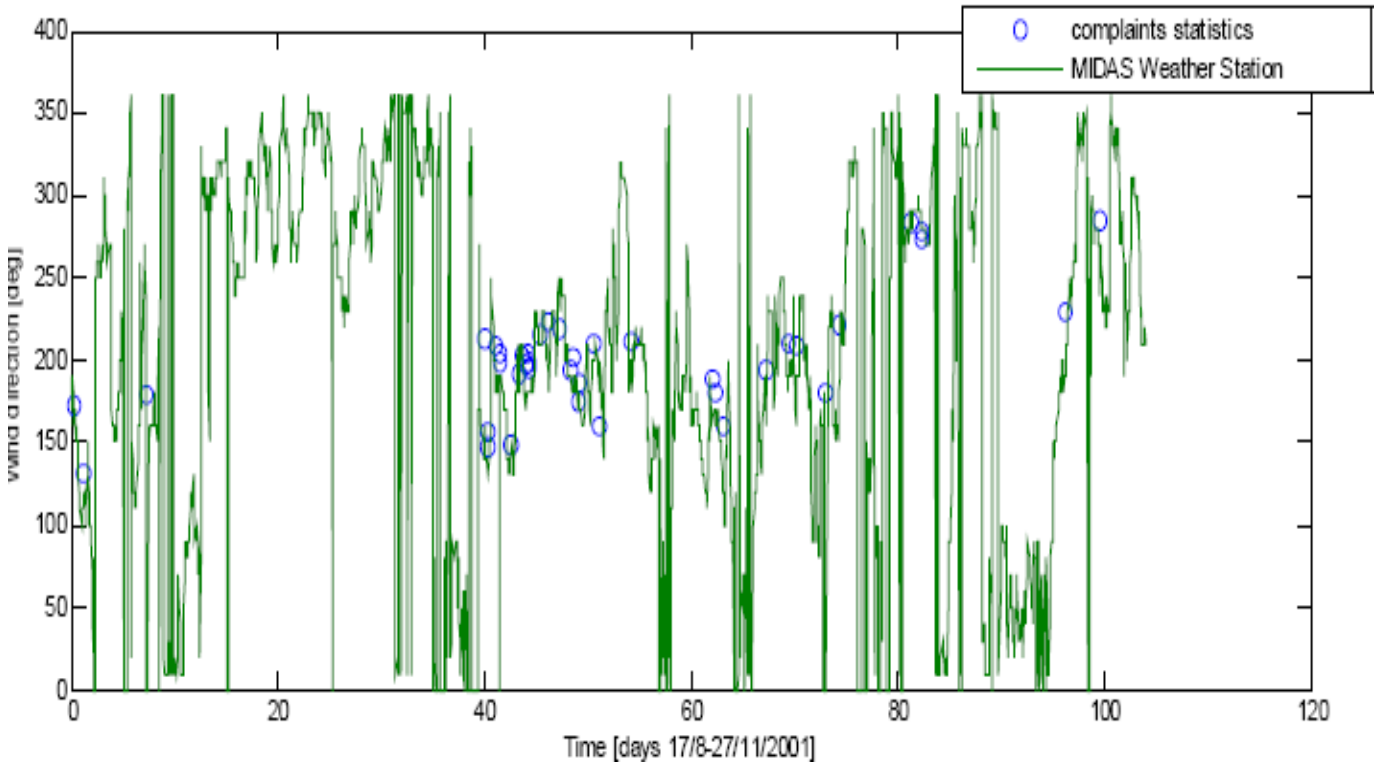
Then calculate, by comparing b. and c, the proportion of the time for which the wind conditions associated with complaints prevail and then target these time for visits and noise surveys in order to maximise the probability of witnessing the problem .

[133] For example, bearings failing on a single turbine leading to a substantial increase in mechanical noise or even debris left over from construction rattling inside a blade as the rotor turned.

[134] See http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file40570.pdf (last viewed 8th March 2011)

Figure 12 Correlation of wind speed and direction with complainant information (from the Salford University AM report).





5.2.1 Wind Speed and Wind Direction

Wind speed is normally directly and proportionally related to the noise emission from a wind turbine i.e. the higher the wind speed the more noise it makes; although the relationship may not be linear and above an upper limit normally tails off so that there is no significant increase.

Wind direction is often an important factor in dictating the degree of wind turbine noise emission at a receptor i.e. noise levels are often highest and/or aggravating characteristics of the wind turbine noise most noticeable when the wind blows directly from the turbine to receptor.

5.2.2 Temperature

Air temperature can influence the propagation of sound, although the effects are frequency dependent and tend to only become significant at large separation distances e.g. more than 1000 metres.

5.2.3 Relative Humidity

Relative humidity can influence the propagation of sound, although the effects are frequency dependent and tend to only become significant at large separation distances e.g. more than 1000 metres.

5.3 Non - Acoustic Related Data

5.3.1 Nature and Character of Locality

As described in the legal review above, balancing the impacts of noise from a wind farm with the nature and character of an area is crucial to the judgment of Statutory Nuisance, as no fixed threshold for Statutory Nuisance applies in all circumstances. For example the degree of noise that is considered acceptable in an urban environment is likely to be greater than in a rural environment; and that the judgment of the nature and character of a location must be based on the existing circumstances i.e. with the wind turbine in place; rather than as it was before the wind turbines became operational. Consequently, a detailed description of the location and its place in its surroundings should be recorded. It may be useful to ask officers in the planning department to assist with this as they are likely to be experienced in objectively assessing and describing the overall nature and character of a location, and be familiar with any formal strategic planning zoning or depiction of the area. However, it is considered that a broad assessment and description of the nature and character of an area should include descriptions of the following:

- The natural and man-made boundaries of the area considered, and reasons for choosing those boundaries;
- The component areas land uses in the locality e.g. rural, sub-urban, urban, wilderness, moorland, hilly, mountainous; farmland (e.g. arable, livestock, grazing/pasture etc.), commercial, residential, industrial, mixed etc;
- The balance of the proportion of component areas and land uses making up the locality;
- Current and historical land uses within the locality;
- The local geology where this is relevant to the nature of the location;
- The topography in the immediate locality of the wind farm and complainants premises, and the wider area of the locality;
- The type and density of any vegetation;
- Human settlement – distribution and density;
- Any juxtaposition of clashing or competing land uses or types

5.3.2 Frequency of Occurrence

Detailed recording of the frequency of occurrence of the problem will be necessary to aid judging and justifying any decision on the existence or otherwise of Statutory Nuisance. A noise problem that happens

frequently over a wide range of wide speeds and directions is more likely to be a Statutory Nuisance; than one that only happens infrequently at a specific wind speed and direction that only tends to occur to for a small minority of the time. This information may be provided by noise and weather surveys at the same time as any investigation, for example by correlating noise problems to specific weather conditions; but some information on frequency of occurrence and associated weather conditions may often have to come directly from the complainant before detailed observations or noise measurements can take place.

5.3.3 Duration

Similarly data on the typical duration of any persistent problem or the range of typical durations of intermittent problems should be recorded, as the longer the duration of a problem the more likely it will be a Statutory Nuisance. Information on duration may be provided by the noise survey; but may have to be supplemented by input from the complainant.

5.3.4 Timing

As a general rule the same level of noise at night is more likely to be Statutory Nuisance compared to in the day time; and less noise than during the day can be a Statutory Nuisance at night. Specific data on the timing of the problem should be recorded as part of any noise survey, and more general data on timing trends should be obtainable from the complainant.

5.3.5 Effects

Information on the effects of the noise should be gathered during any investigation i.e. sleep and / or activity disturbance. If attended measurements or observations are made as part of the investigation, those making the visits can record their qualitative observations of the effects of the noise.

5.4 Acoustic Data

Legislation concerning Statutory Nuisance does not state noise level thresholds for statutory nuisance; and case law has established that noise measurements are not required to prove statutory nuisance[135]. However, the subjective assessment and acceptability of noise varies markedly between individuals and can be volatile over time for an individual. These factors can make judgements in regard to noise Statutory Nuisance difficult and open to challenge. Additionally Magistrates and Judges may find reliance solely on qualitative information uncertain and can prefer supplementary quantitative data helpful in fully understanding specific cases and deciding whether Statutory Nuisance exists and the degree to which it needs to be abated or restricted. Qualitative observations and evidence from complainants are important to carrying out an investigation, but noise measurements can also be useful as part of the investigation of wind farm noise complaints for reasons including:

- Unattended noise level measurements can be carried out more easily and cost effectively for long periods than attended qualitative observations;
- Providing noise level based information to a wind farm operator may help facilitate a rapid remedial and collaborative response to an initial or informal approach by a local authority, which can sometimes resolve noise problems more quickly than the formal Statutory Nuisance procedure;
- Noise measurements can provide information to support qualitative assessments regarding the presence of an adverse noise impact; and thereby help counteract claims of inconsistency, unduly high expectations, over-zealousness, inexperience and unreasonableness against investigating officers or complainants;
- It is common in contested cases involving commercial interests that the defence will introduce noise measurements or noise level standards and guidelines as means of justification of the noise problem, it can be difficult to counter the apparent scientific rigour of such an approach without undertaking noise measurements;

[135] *London Borough of Lewisham Vs Yvonne Hall* [2002] EWHC 960 Admin

Noise measurements are often important in rebutting attempted Best Practicable Means (BPM) defences or establishing to what degree a nuisance should be restricted if a BPM defence applies.

A potential limitation to using noise measurements is that some of the characteristics of a noise which enhance its impact compared to a noise of similar level, but without the aggravating characteristics, do not lend themselves to easy measurement or quantification.

In regard to Statutory Nuisance, the measurement of noise should be complementary to and not dominate the qualitative observation and subjective assessment of impacts; as so many other factors apart from the intensity and physical characteristics of noise are relevant to deciding on Statutory Nuisance. However, quantification of noise is attractive to many decision makers, who are already confronted with a difficult judgement process; as it can appear more precise and less uncertain than qualitative methods. In which case this report advises that local authorities should carefully consider the need for noise measurements and where considered appropriate carry them out in a demonstrably effective manner. The following are a range of matters that the Author regards as important considerations when contemplating taking noise measurements.

5.4.1 Instrumentation

Any noise measuring equipment should comply with the requirements of Class 1 of British Standard BS EN 61672-1:2003 "Electroacoustics - Specification." for broadband measurements; and BS EN 61260: IEC 61260 for octave or fractional octave band measurements.

Any sound pressure levels, should be measured using the Fast (125 millisecond) time constant.

5.4.2 Calibration

Noise measuring equipment should, within a period of not more than 24 months before being used, be verified, together with an acoustic calibrator or pistonphone, in accordance with BS 7580: Part 1:1997 'Specification for the verification of sound level meters.'

A sound level meter should always be field calibrated with the appropriate field calibrator before and after any measurements, and the results recorded and included in any report of findings.

5.4.3 Self Noise

The self noise of the sound level meter should be sufficiently low to allow adequate recording of noise levels in the particular location, this becomes a more important consideration in very low background noise levels.

5.4.4 Windscreens

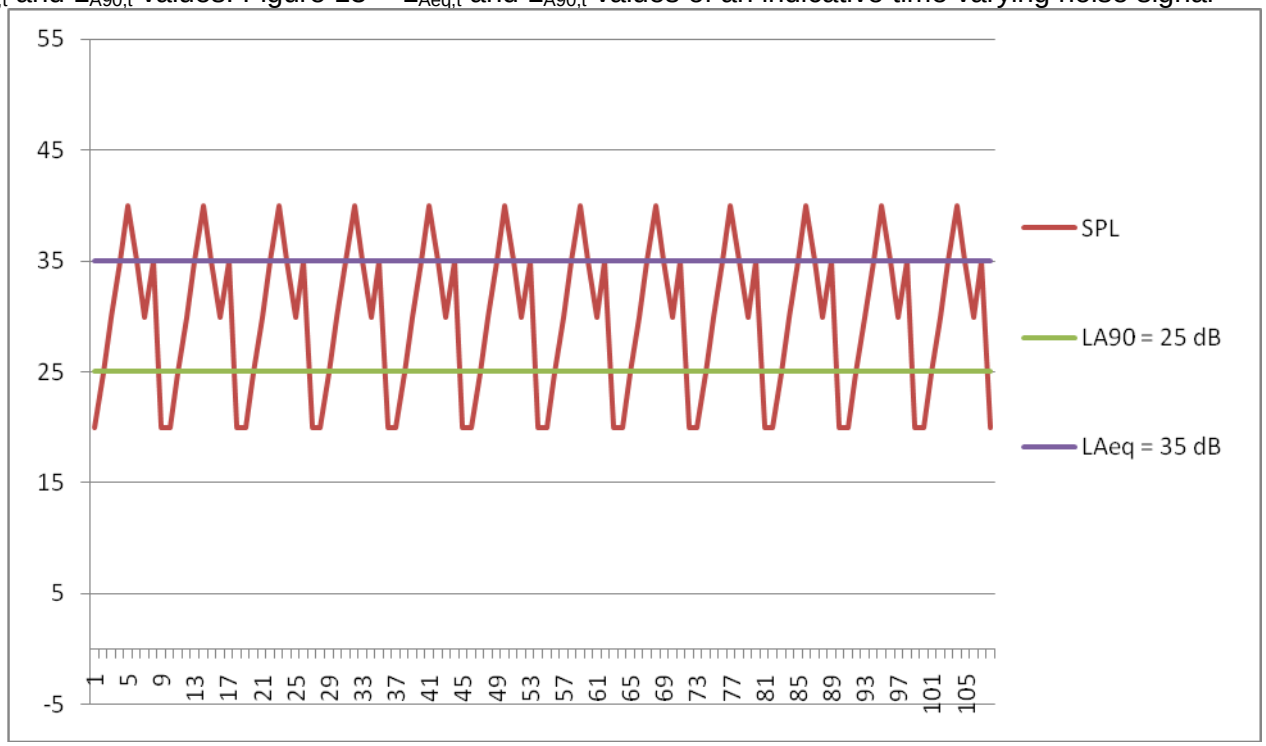
Wind induced microphone noise is a problem that affects most outdoor acoustic measurements. The interaction between the local wind and turbulence with the surfaces of the microphone generates non-acoustic pressure fluctuations at the microphone diaphragm that significantly affect the microphone output. Various types of wind shields are used to overcome this problem but the benefit of these measures may not be well quantified. This issue is particularly relevant in the context wind farm noise surveys, where the correlation of ambient noise as a function of the local wind speed is of importance when determining the noise criteria and undertaking noise measurements if investigating complaints. There are a range of commercially available wind shields. It is recommended that before engaging in a wind turbine noise survey the microphone wind noise attenuating characteristics of the microphone wind screen are checked with the manufacturer and only those that minimise the influence on the recorded noise level are used. Research has established that that an important variable in wind screen performance is the diameter of the windscreen, with the larger wind screens, with a two-layer construction generally performing most effectively for A-weighted measurements[136].

[136] The matter is discussed in the report ETSU W /13/00503/REP – Noise Immission from Wind Turbines; and the following research - *Hessler G, Hessler D, Brandstatt D & Bay K, Experimental study to determine wind induced noise and wind screen attenuation effects on microphone response for environmental wind turbine and other applications. Noise Control Engineering (56) 4 July-August 2008; and Leclercq D, Cooper J & Stead M , The use of microphone windshields for outdoors noise measurements, Proceedings of ACOUSTICS 2008, 24-26 November 2008, Geelong, Australia*

5.4.5 Noise Indices

By convention wind farm noise in the UK is measured using the $L_{A90,10\ minute}$ noise index, as it is argued that this index minimises the influence of extraneous noise. However, excepting ETSU –R-97, there are few if any standards that set noise limits using this index. Additionally, it is argued that because the $L_{A90,10\ min}$ index focuses on the quietest periods in the measurement period it is relatively insensitive to rapid fluctuations in noise level where the noise varies rapidly over a short period e.g. as with aerodynamic/amplitude modulation, and the impact of such characteristics can be underestimated using the $L_{A90,t}$ noise index.

However, elsewhere in the world[137] the $L_{Aeq,t}$ index is preferred for wind turbine noise. Use of the $L_{Aeq,t}$ or derivatives for environmental noise measurement is recommended by international standards and bodies e.g. ISO 1996 and the WHO, and British Standards such as BS 4142, BS 7445 and BS 8223. Additionally there are a range of standards and guidance that offer guideline and recommended values of $L_{Aeq.T}$ noise levels against which to weigh any measurement. The energy averaging nature of this index means it tends to be biased towards the highest noise levels that occur during a measurement. The figure below shows an indicative sound pressure level trace of a time varying noise signal (SPL) and the approximate $L_{Aeq,t}$ and $L_{A90,t}$ values. Figure 13 $L_{Aeq,t}$ and $L_{A90,t}$ values of an indicative time varying noise signal



Because there are no fixed decibel level and noise index based standards that act as thresholds for the onset or as a definitive test for Statutory Nuisance, the primary uses of noise measurement will be establishing the intensity of the noise complained of and whether an established threshold of impact is being exceeded as an indicator of impact; and to assist in deciding if the complainant is being more than ordinarily sensitive. Consequently, the choice of noise index will depend on what guideline, standard or limit value is used to assist in making this judgment or articulating the reasons for a decision.

As a result the investigator may wish to consider measuring a range of noise indices e.g. L_{Aeq}, L_{A1}. L_{A10}, L_{Amax}, L_{A90} and L_{A99} for comparison with specific guidelines and standards etc. This range of noise indices may also be useful as a means of demonstrating specific characteristics of the noise that may aggravate its impacts.

[137] *For example Germany, Denmark , Sweden, United States, Canada etc.*

5.4.6 Weighting

The most commonly found weightings on sound level meters are “A” or “C”, which designate a way in which the sounds measured by a sound level meter can be filtered to represent the non-linear frequency and intensity dependent sensitivity of the human hearing system.

A - weighting is most commonly used for overall environmental noise impact assessment, as over time a plethora of studies, standards and guidance that offer guideline and recommended values using the A-weighted decibel have been developed.

C-weighting is sometimes advanced as an alternative weighting, particularly as it is less discriminatory towards low frequency noise than A-weighting. Noise measurements using C weighted decibels will often show higher values and a greater sensitivity to changes in the intensity of the low frequency noise compared to measurements using the A-weighted decibel.

However, many standards and criteria based on measurements correlated with typical subjective response have been developed using the A-weighted decibel, and few use the C-weighted decibel. This means that despite the difference in sensitivity and absolute values of A and C weighted decibels, reasonable correlations with subjective response to noise with low frequency content have been established using the A-weighted decibel; and guidelines, limits and assessment criteria have been subsequently derived using the A-weighted decibel.

Consequently, where a noise level guideline, limit or assessment value is stipulated using the A-weighted decibel, even though it may be possible to change to using the C-weighted decibel, in order to maintain a correlation with subjective response equivalent with the A-weighted, the new C-weighted guideline, limit or assessment decibel value must be revised substantially upwards. However, there is little or no research into the correlation between the subjective response and C-weighted noise levels that allows this correction to be made. Some have proposed deriving a C-weighted limit value by adding 10 or 20 dB arbitrarily to the dBA guidelines; but this would result in many non-annoying sounds being re-labelled as being non-compliant. Some examples of normal background sounds that would, if assessed with such dBC derived criteria, which would be out of compliance, include the wind itself at moderate to high wind speeds, virtually all road traffic noise and urban locations, and many rivers and coast lines. Consequently, this report cautions against using the C-weighted decibel to assess wind turbine noise.

5.4.7 Frequency Analysis

Notwithstanding the comments made below in regard to problems with façade low frequency measurements and the effects of room acoustics, frequency analysis of wind turbine noise can be helpful in assessing and articulating its impact, particularly when the noise contains discrete tonal elements or modulations are enhanced in discrete frequency bands..

In this regard a relatively simple 1/3 octave band based screening method for assessing tonality is found in BS 7445:1997 - Description and measurement of environmental noise — Part 2: Guide to the acquisition of data pertinent to land use; in the note to section 4.1.2.

A more sophisticated method, largely based on the Joint Nordic Method (JNM), for assessing tonality is found in ETSU-R-97. A review of the assessment of tonality provided in a 2005 paper by Berry and Porter[138]; comments on the JNM as follows:

“The Joint Nordic Method presents a method for assessing the audibility of tones in noise. It has been widely tested on both artificial and environmental sounds. It appears to be the most adopted method in Europe for assessing the audibility of tones in noise. In particular variations of this method have been used for wind turbine noise. It is included in the draft ISO standard ISO 1996 ‘Description and measurement of environmental noise’, Part 2, Annex C. It has identified shortcomings in relation to non-

[138] *Berry B & Porter N, A review of methods for quantifying tonal and impulsive features; Internoise 2005, Environmental Noise Control, Rio de Janero, Brazil*

stationary (time varying) signals. Additionally, research findings also suggested that trackable non-stationary behaviour of frequency modulated tones leads to difficulties when using tonal metrics that are derived from estimated spectra." i.e. the method may not be suitable for assessing time varying noise.

However, the Berry and Porter paper reviewed a number of methods of assessing the prominence of tones and comments as follows:

"*For the limited analysis that was completed, we found that the Draft ISO 1996-2 Annex C method was not superior to two of the objective methods tested by Daniel et al, namely E DIN 45681 2002, ANSI S1.13, but was similar to (and even slightly better than) ANSI S1.13 PR, based on the regression fit.* "

However the Berry and Porter review raises several important issues as to the practical implementation of the methods reviewed by commenting as follows:

"*In terms of implementation, we have found that tonal analysis using instrumentation with specifically included tonal options may in practice be more difficult than one would expect, as one would have to have a dedicated instrument readily available. These instruments can be fairly costly and do not appear to be held by the average environmental officer or consultant. Post-processing may be the more common option available to all but is more time and labour intensive.* "

Consequently, if engaging in assessment of tonality of noise from wind farms the Author suggests that unless there are good reasons not to do so, the method described in ETSU-R-97 should be used.

5.4.8 Measurement Time Period

Conventionally wind farm noise is measured over 10 minute periods, and measurements over such a period can be directly correlated to equivalent 10 minute mean wind speeds. However, whilst this is adequate for most circumstances, a 10 minute measurement period might not capture adequate data to describe the situation if the signal varies significantly over a much shorter time period.

Most modern noise measuring equipment or data loggers, have large data storage capability, and many sound level meters can measure and record data in a format that can be post processed over any time period e.g. by using short Leqs - 125 milliseconds. This flexibility can be valuable as it avoids having to decide on the measurement time period prior to commencing a noise survey; and can allow interrogation of data in a manner that visually articulates any specific temporal characteristics of the noise that may aggravate its impacts.

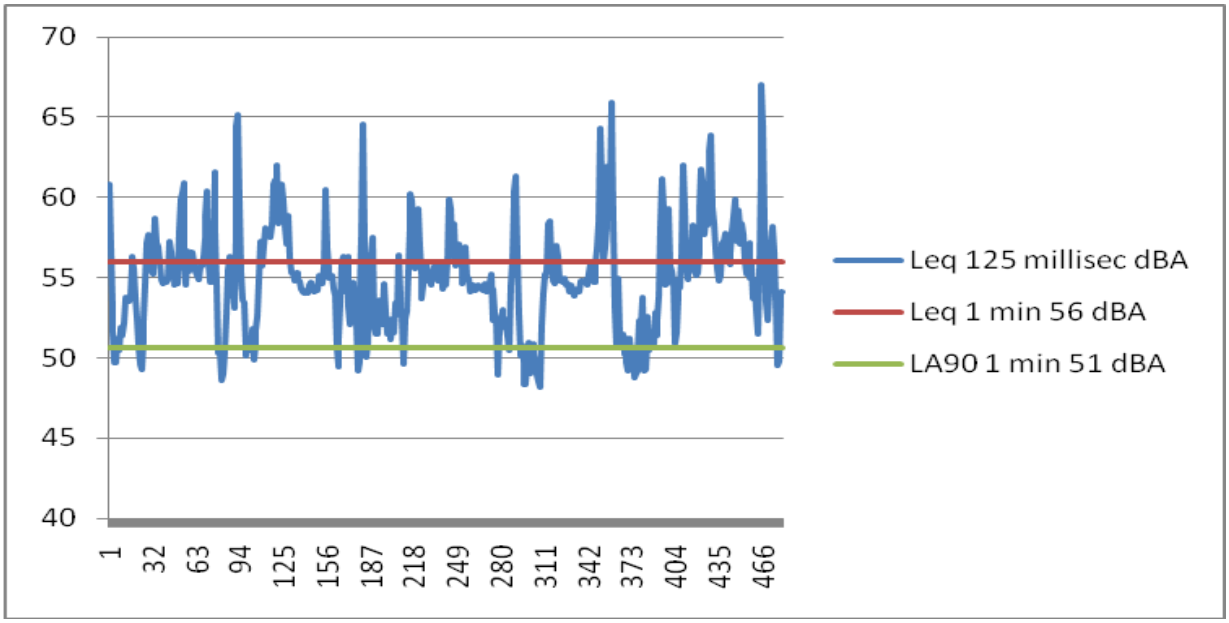


Figure 14: Example of post processed short Leqs (125 milliseconds) of a significantly time varying noise signal

5.4.9 Survey Duration

Due to the significant effects of wind speed and direction on the emission of wind turbine noise and immission levels of noise at the receptor, it is not possible to prescribe either a minimum or maximum survey duration in terms of number of days etc. However, generally, and provided the survey has been planned taking into account factors that may influence noise emission from the wind turbines e.g. wind speed and direction, and the operation of the wind farm[139]; it might be possible with good planning based on prior information as to the likelihood of the noise occurring, to capture adequate information over a relatively short period. However, in some circumstances a more prolonged survey or a series of planned surveys over a longer period will be necessary in order to capture sufficient data over a wide enough range of wind speeds and directions to adequately investigate complaints, and decide on the appropriate course of action.

Generally any noise survey should be carried out over sufficient time to provide an appropriate number of valid data points across the range of wind conditions considered to be critical. These are likely to be the wind conditions which prevail when the complainant alleges the noise nuisance occurs. As a suggested guide to how much data and therefore how long a survey should be it is worthwhile considering the advice in ETSU–R–97 in regard to compliance testing. This advises taking 20-30 measurements, each of 10 minutes duration, at wind speeds within +/- 2 metre per second of the critical wind speed/direction, with ideally at least 10 measurements either side of the critical wind speed/direction.

In most cases wind speeds of up to 12 metres per second will be adequate, however higher wind speeds may be justified in certain cases. Valid data points are those that remain after the following data have been excluded:

- All periods during rainfall;
- All periods during which the measurement position is not within 45 degrees of being downwind of any wind turbine; and
- All periods during which turbine operation was not normal.

5.4.10 Sound Recording

Much modern sound measuring equipment also offers the option of digitally recording the sound that is being measured. This can be useful in allowing the investigating officers to target any analysis of unattended noise measurements to periods with and without the problem noise, and to correlate such measurements with meteorological data.

5.4.11 Correction for Extraneous Noise

In some instances it may be necessary to undertake corrections of the measured levels, Lc, for the influence of background noise. For $L_{Aeq,t}$ noise levels this may be achieved by repeating the measurement process with the wind farm not in operation and determining the background noise at the assessed wind speed, Lb. The wind farm noise, Leq_{WF}, is then calculated as follows:

$$Leq_{WF} = 10 \times Log_{10}\left(10^{(Lc/10)} - 10^{(Lb/10)}\right)$$

In order to determine a typical specific noise level for each integer wind speed (or band of integer wind speeds) a linear regression may be performed on the data set. As well as the typical noise level determined in this manner, it may also be appropriate for the investigating officer to consider the range and spread of the specific noise level arising from the wind farm.

[139] Wind turbine operation can vary considerably over a year, not only due to seasonal wind conditions but also maintenance and repair requirements.

ETSU – R – 97 advises that the above decibel subtraction method is not strictly applicable to statistical noise indices e.g. $L_{A90,}$ for time varying noises and refers the reader to a paper describing complex methods of predicting such indices for road traffic noise. Using such methods will only be required when using statistical noise indices where the wind turbine noise varies significantly with time compared to the background noise.

5.4.12 Microphone Location

5.4.12.1 Internal

Where a complainant advises that the impacts arise primarily inside their property it may be advisable to undertake internal measurements and observations. However, noise measurements within buildings can be inconsistent due to the influence of room acoustics e.g. standing waves, acoustic reflections from surfaces and absorption from soft furnishings, carpets and beds etc; creating non-diffuse sound fields that could result in under or overestimation of the typical exposure in the room.

Additional problems with determining noise levels inside a building can be caused by constraints on access; and interference from noise generated internally that can limit the duration of any internal noise survey and/or contaminate noise measurements. However a number of techniques may be used to overcome such difficulties. The most reliable method will be to plan the investigation to visit the dwelling and take attended measurements and / or calibrated recordings inside the dwelling at times when the noise is most likely to occur. Alternatively, a carefully calibrated nuisance recorder incorporating a sound level meter could be used to record audio events and take noise measurements when the recorder is remotely activated by the complainant. This method is less preferable to the attended recordings because it is often difficult to subjectively listen to or analyse the recording using headphones or speakers in a different room; although quantitative scrutiny of noise levels is still normally viable; and residents may not record noise and measurements at appropriate times for suitable periods.

The presence of persons other than the investigating officer/consultant in the room may have an effect on the measured level as a consequence of additional absorption in the room. In addition anyone in the room other than the officer actually carrying out the measurement must be at least 1m away from the microphone, as it at frequencies of around 300Hz to 1 KHz acoustic reflections from a person may cause significant errors when measuring at less than 1m away from a person[140].

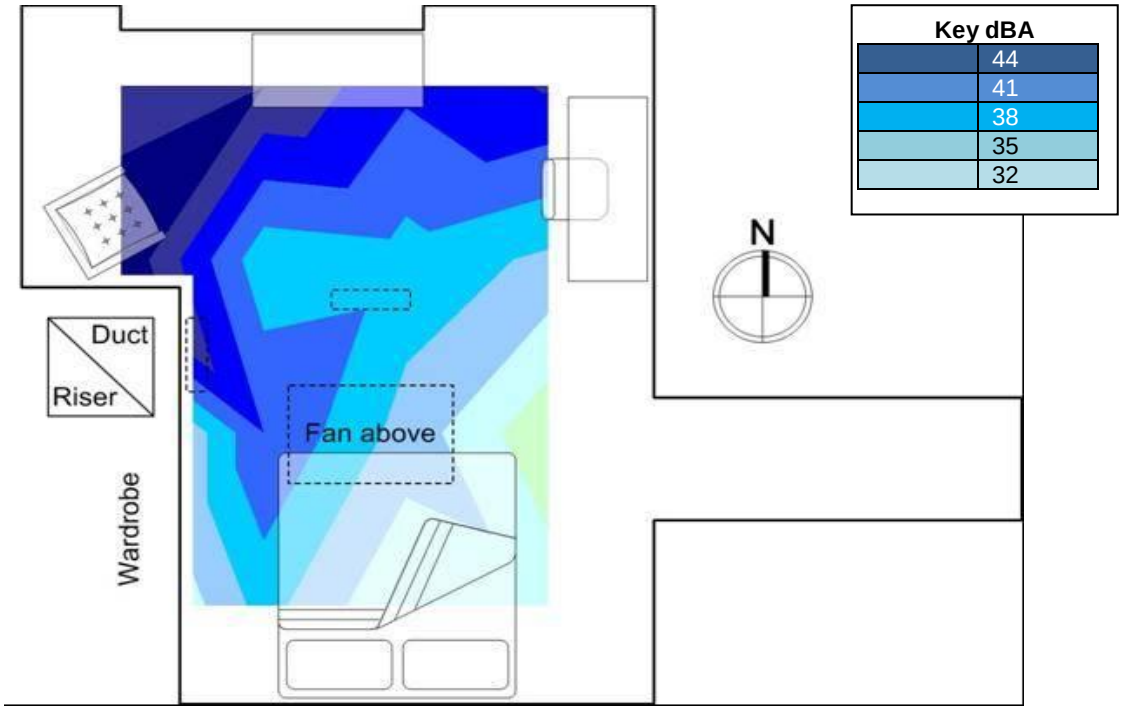
The effects of sound reflections and absorption can be appropriately managed by following the advice for façade noise insulation measurements in BS EN ISO 140-5:1998 i.e. the microphone shall be positioned at least 0.5m from any sound reflecting vertical room surface and from any sound absorbing objects such as items of furniture or curtains etc. and be located at a height of 1.2-1.5m from the floor.

Multiple noise measurements can be used to “map” levels across the room; in which case microphone positions should not be closer than 0.7 m[141]. The figure below is based on a number of grid measurements plotted using a spreadsheet programme, which shows noise level distribution across a bedroom.

[140] *B&K Acoustic Noise Measurements (1988) and Young R.W. Can accurate measurement be made with a sound level meter held in the hand? Sound Vol 1 Jan – Feb 1962*

[141] *Section 8.1.2 of ISO 1996: p2*

Figure 15 Plot of Noise Measurements Across a Bedroom



Alternatively, it may be simpler to measure noise levels at a point in the room where persons are likely to spend the most time, in order to obtain typical exposure data e.g. at seated head height in a living room and at the bed head in a bedroom; as these measurements would include the standing waves, room modes, sound absorption and reflection effects and any other location specific acoustic effects, as they affect the ordinary use of that part of the premises.

Further advice on internal noise measurements can be found in the Association of Noise Consultants Guidelines for Noise Measurements in Buildings (ANC 9801) pt 2 Noise from External Sources (1998) and standards in regard to facade noise insulation measurements e.g. BS EN ISO 140-5:1998.

5.4.12.2 External

Several existing standards for assessing noise impacts use external based measurements as proxies for internal impacts i.e. BS 4142 and ETSU-R-97.

External noise measurements have the advantage that in many cases it will be possible to carry out unattended external measurements for a significant period of time, so that an appropriate range of wind and other meteorological conditions are covered.

As far as possible, the measurements should be made in “free-field” conditions i.e. free from significant influence of reflections other than from the ground. To achieve this, the microphone should be placed at least 3.5 m away from the building facade or any reflecting surface except the ground. In the event that access is not possible, for whatever reason, to the complainant’s property, then measurement and assessment of the level of noise immission from the wind farm could be made at the nearest publicly accessible location as a proxy provided the following conditions are met:

- wind farm noise immission and background noise levels are similar to those at the receptor;

- the microphone location is at a similar height and over similar terrain to the original receptor location;
- the distance to the wind turbine is the same as the original distance within +/- 5%;
- the angular position of the measurement location is the same with respect to the wind turbine within;
- +/-5° (10°for measurement in the downwind direction); and,
- any screening effects between the wind turbines and the complainant's premises are similar.

The advice in ETSU-R-97 on compliance testing suggests that noise measurements should be synchronised with measurements of the wind speed and, where available, with operational data from the turbine control systems of the wind farm. In addition to the foregoing, information should be sought from the wind farm operator as to the operational modes of the turbines throughout the survey period, with specific attention given to any abnormal operation or activities which may have rendered the turbines inoperable or to have given rise to other anomalies and whether the operation was typical or during any seasonal lull or peak in power generation – again this information should be correlated to the wind and noise measurement periods.

In order to determine a typical specific noise level for each integer wind speed (or band of integer wind speeds) a regression analysis may be performed on the data set. As well as the typical noise level determined in this manner, it may also be appropriate for the investigating officer to consider the range and spread of the specific noise level arising from the wind farm.

5.4.12.3 Combined Internal and External Measurements

Many noise measurement systems can operate and record data on more than one channel. This allows the investigator the freedom to choose to simultaneously measure internal and externally. This will have the benefits and dis-advantages of internal and external measurements as outlined above but will generate a large data set which should cover all the likely affected areas and effects.

5.4.12.4 Free-field

Free-field conditions exist when the microphone is placed in a location un-influenced by noise reflections other than from the ground. This is normally an external location and presents a simplified standard measurement situation, but introduces several uncertainties due to the number of assumptions that will need to be made when converting the noise measurements to equivalent internal values.

5.4.12.5 Façade

In some circumstances it will not be possible to take free-field noise measurements and the only practicable measurement location is close to a façade or other vertical sound reflecting surface. Sound reflections off the façade normally mean broadband A-weighted noise levels measured 1 to 2 metres from a façade which will be approximately 3 dBA higher than if there were no reflections i.e. the measurement was in "free-field" conditions unaffected by acoustic reflections other than off the ground. However, at low frequencies i.e. below about 200 Hz, acoustic reflections do not necessarily follow the conventional "*acoustic reflection equals + 3 dB*" rule of thumb at 1 to 2 metres from a façade; and this is likely to make measurements of low frequency noise unreliable (although due to the weighting corrections, A-weighted measurements are normally reliable).

The National Noise Incidence Study 2000 (England and Wales), considered the importance of façade reflections in section 3.2 of Client report number 204271f[142]. Where the study states:

> *"Hall et al[143] analysed road traffic noise at two assessment positions, the first was 2m in front of the façade and the second was flush with the surface of the façade. (N.B. Both of these positions can be used in BS EN ISO 140-5:1998 field measurements.) The*

[142] *National Noise Incidence Study (2000) (England and Wales): 1.2m and 4m assessment heights: Client report number 204271f*
[143] *Hall FL, Papakyriakou MJ, Quirt JD, Comparison of outdoor microphone locations for measuring sound insulation of building facades. Journal of Sound and Vibration 92(4), 559-567.*

position at the surface should result in pressure doubling (i.e. 6dB higher levels than the incident level) whereas the position 2m from the façade should result in energy doubling (i.e. 3dB higher levels than the incident level). The authors were investigating (a) whether a 3dB level difference between these two positions was reasonable, and (b) if there were reasons to prefer one microphone position to the other. They concluded (a) that the 3dB conversion was reasonable for 200Hz – 2kHz, but gave misleading results below 200Hz, and (b) that the site to site variation between the two positions should be minimised by preferring only one position, however, it was not possible to identify the preferred position from the available data."

And

"From a comparison of measured and predicted data, Quirt[144] concluded that the assumption of energy doubling at 2m from the façade was reasonable for a distributed source such as road traffic in third octave bands above 100Hz."

The NNIS commentary and the two papers referred to above illustrate that the facade reflection effects at low frequencies make already difficult measurements unreliable when not undertaken in free field conditions; and that below 200Hz simple façade conversion corrections to give equivalent internal values are unlikely to be accurate. Consequently, due to the unreliability of low frequency measurements, if frequency analysis is to be part of the investigation it is recommended it is carried out in "free-field" conditions in the absence of reflections other than from the ground.

5.5 Wind Farm Related Data

5.5.1 Data from the Wind Farm Operator

In addition to the foregoing, information can be sought from the wind farm operator as to the operational modes of the turbines throughout the investigation period, with specific attention given to any abnormal operation or activities which may have rendered the turbines inoperable or to have given rise to other anomalies – again this information is best correlated to the noise survey measurements and weather monitoring information. Data that it might be useful to request from a wind farm operator includes the following:

- Any wind and other meteorological data they may have for the site;
- Number and Type of turbine/s;
- Typical electrical power output profile over a year;
- Planning noise assessment;
- Noise mitigation and management methods;
- Any proposed noise mitigation and management methods;
- Any reasonable excuses for the noise problem.

5.6 Data analysis and Interpretation

5.6.1 Subjective Response to Noise

Extensive research into noise annoyance[145] and disturbance over many decades has shown that although average long-term effects e.g. annoyance, can be determined by asking a representative sample of a population to rate their individual annoyance on a numerical or category scale such as '*not annoyed, 'a little annoyed', 'moderately annoyed* or *'annoyed very much*', these responses tend to be only weakly linked with the degree of sound exposure. This modest correlation reflects very large differences between individuals' reactions to the same noise (due to the modifying non-acoustic factors such as

[144] *Quirt JD, Sound fields near exterior building surfaces. Journal of the Acoustical Society of America 77(2), 1985, 557-566.*

[145] *The WHO guidelines for Community Noise (2000) provide a definition of noise annoyance as "a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Lindvall & Radford 1973; Koelega 1987)".*

feelings to the noise maker, personality traits, perception of control over the noise and noise sensitivity etc.) rather than a failure of experimental design.

The Figure 16 below shows an indicative chart of the 'percentage highly annoyed' of a sample of a population plotted against noise exposure level based on data from numerous social survey studies of transportation noise carried out in different countries[146]. Each point in the diagram represents the response of a sample of respondents exposed to a particular level of noise. The curve is a 'best fit' to the scattered data points, and the general shape has been re-confirmed more recently[147] by further research which shows the similar scattering of data points.

The purpose of reproducing this chart here is to illustrate how a statistical estimate of the underlying trend between annoyance and a noise index can be developed for a population as a whole, even though the scatter of data i.e. the variability of individual sensitivity, is high; as shown by the deviation of individual points from the trend lines in Figure 16. Environmental noise assessment is not sufficiently precise, primarily due to the substantial variation in sensitivity to noise across a population, to enable the subjective reaction of individuals to be confidently predicted. Consequently, event noise levels and noise exposure contours only provide indications of the likely extent and severity of the general effects of noise on communities but due to the significant variability and volatility of individual subjective response to noise, and the significant influence of non-acoustic factors on these traits, they cannot indicate accurately how particular individuals will react.

Despite these limitations, the curve in Figure 16 illustrates the probable form of the relationship between noise exposure and community annoyance. It aggregates results from many surveys in different countries and may be considered typical, if not average. Any point on a dose response curve, such as the one below, represents the average or typical response found in a particular study, not that of an individual. Furthermore, it can be seen that there is no point at which the noise clearly ceases to be "acceptable" and instead becomes "intolerable". Thus any standards and guidelines, including those discussed below, tend to represent a compromise between reducing the level of annoyance to zero, and any economic, social, environmental, historical and political constraints that are also important.

[146] *Schultz, T.J: Synthesis of Social Surveys on Noise Annoyance J. Acoust. Soc. America, 64, 377-405, 1978; Fidell, S., Barber, D.S., Schultz, T. J: Updating a Dosage-Effect Relationship for the Prevalence of Annoyance Due to General Transportation Noise. J. Acoust. Soc. America, 89, 221 - 233, 1991.*

[147] *Fidell, S. (2003). The Schultz curve 25 years later: A research perspective. J. Acoustical Society of America 114(6), 3007-3015; Fidell, S. & Silvati, L. (2004). Parsimonious alternative to regression analysis for characterizing prevalence rates of aircraft noise annoyance. Noise Control Engineering Journal, 5(2), March/April, 56-68; and, Miedema, H. M. E., Vos, H. (1998) Exposure response functions for transportation noise. Journal Acoustical Society of America 104, 3432-3445.*

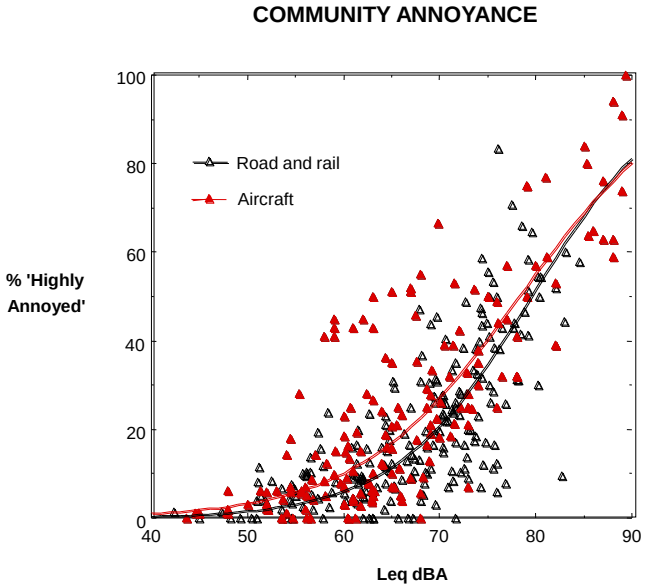


Figure 16 General Response to Noise (after Schultz) (source draft IEMA/IOA Guidelines for Noise impact Assessment of Noise 2002)

5.6.2 Noise Assessment Methods

There are three main noise level based methods[148] available to assess the likelihood of noise causing a disturbance to residents, as summarised below.

5.6.2.1 Benchmark Assessment – Absolute (Fixed Limits)

Benchmark noise impact assessments are made by comparing specific sound levels against established benchmark values defined in existing standards and regulations. Should specific sound levels exceed any defined benchmarks this is taken as indicative of negative impacts of the noise under consideration.

Examples of this type of assessment are BS 8233:1999 - Sound Insulation and Noise Reduction for Buildings Code of Practice or the WHO Guidelines for Community Noise (1999), which are summarised below.

5.6.3 BS 8233:1999

Guidance within BS 8233:1999 *'Sound Insulation and Noise Reduction for Buildings – Code of Practice'* sets out recommended internal noise levels for acceptable living and working conditions, set out in Table 2. It is acknowledged that in BS 8233 the design targets are in relation to anonymous noise. However, the standard advises that the recommended noise levels only apply to noise that is anonymous, steady, continual and broadband in nature.

Table 2: Recommended Internal Living and Working Noise Levels (BS 8233)

Criterion	**Typical situations**	**Design range $L_{Aeq,T}$, dB**	
		Good	**Reasonable**
Reasonable resting/sleeping conditions	Living rooms	30	40
	Bedrooms	30	35

Note: For Reasonable conditions for resting and sleeping at night the noise from individual noise events should not exceed 45 dB L_{Amax} in bedrooms. dB re 20 μPa.

[148] Draft BS 9142 – Guidelines for Environmental Noise Management (2002).

In addition, the guidance suggests that a desirable noise level in gardens and balconies is 50 dB $L_{Aeq,T}$ and 55 dB $L_{Aeq,T}$ should be regarded as the upper limit.

Section 7.3 of BS 8233:1999 advises that "normally only the upper noise limit will need to be decided" i.e. that in most circumstances only the "reasonable" noise levels from BS 8233 need be achieved.

5.6.4 World Health Organisation - Daytime Noise Levels

The guidance level of 55 dBA is also the acceptable noise level at the façade of noise sensitive properties according to The World Health Organisation's (WHO) '*Guidelines for Community Noise*' report for external environmental noise levels that:

'During the daytime, few people are seriously annoyed by activities with L_{Aeq} levels below 55 dB; or moderately annoyed with L_{Aeq} levels below 50 dB...'..'

Table 4.1 of the WHO guidelines recommends environmental daytime and evening limits of 55 dB L_{Aeq} or less over the 16 hour daytime period (07.00-23.00) '*to avoid minimal serious annoyance'*, and 50 dB L_{Aeq} '*to avoid minimal moderate annoyance'*.

5.6.5 World Health Organisation - Night-time Noise Levels

For night-time noise sources the WHO Community Noise guidelines recommend a night-time (23.00-07.00) noise level of 45 dB $L_{Aeq,8h}$ 'outside bedroom windows' (for a continuous steady noise source, and open windows) and on a sleep disturbance basis the WHO guidelines state in Section 3.3 that:
'*For a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45 dB LAmax more than 10-15 times per night……*'

5.6.6 World Health Organisation Office for Europe – Night Noise guidelines for Europe

In 2003, the WHO Regional Office for Europe set up a working group of experts to provide scientific advice for the development of guidelines for future legislation and policy action in the area of control and surveillance of night noise exposure.

The working group consisted of experts from many fields including sleep research, acoustics, psychology and epidemiology. In 2006, the working group and stakeholders from industry, government and non-governmental organisations reviewed and reached general agreement on an initial set of guideline values for the final document, based on values below which no observable adverse effect was detected (NOAEL)[149] which was published on the EU web site in 2007.

Since the publication of the initial guidelines, various comments were received regarding the achievability of the guideline values. In response, WHO in consultation with international experts and stakeholders including the EU agreed that the guidelines should be based on the lowest observed adverse effects level (LOAEL)[150] rather than the no observed level (NOEL). In addition, an interim target was also introduced as a feasibility-based guideline. These findings were published in 2009 and it is this version of the *Night Noise Guidelines for Europe (NNGS)* that are current[151].

The latest NNGs do not supplant the existing WHO Community Noise Guidelines and are described in the document as complementing them.

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[149] *NOEL – No Observed Effect Level - This is the level below which no effect can be detected. In simple terms, below this level, there is no detectable effect on health and quality of life due to the noise.*
[150] *LOAEL – Lowest Observed Adverse Effect Level - This is the level above which adverse effects on health and quality of life can be detected.*
[151] *See http://www.euro.who.int/document/e92845.pdf (last viewed 8th March 2011)*

The NNGs specify use of the cumulative annual metric L_{night} – the annual average equivalent sound level between 23:00 and 07:00 — to protect against sleep disturbance.. There are two recommended values as follows:

- Night noise guideline (NNG) $L_{night,outside}$ = 40 dBA
- Interim target (IT) $L_{night,outside}$ = 55 dBA

The NNGs are aiming to prevent impacts on sleep including sub-awakening effects on sleep patterns. But these sub-awakening impacts may not be pathological *per se* as they are part of the physiology of otherwise undisturbed sleep and may have no significant effect on sleep quality or duration for the majority of the population; e.g. in an eight hour undisturbed night for a healthy sleeper, on average 24 spontaneous EEG awakenings can be observed[152].

The NNGs are widely exceeded across the UK and Europe; but the NNG is regarded as an ultimate aspirational objective, and the Interim Target as a more pragmatic level to be aimed for in the meanwhile.

5.6.7 World Health Organisation Guidelines – Application

In 1998 The UK Department of the Environment, Transport and the Regions (DETR) requested the National Physical Laboratory (NPL) together with the Institute of Sound and Vibration Research (ISVR) at Southampton University, review noise standards used for assessing the health impact of environmental noise. The outcomes of this research[153] confirmed that the scientific evidence suggests thresholds below which it is unlikely that there is an impact on health, and that the 1995 Karalinska Institute guideline values (which were adopted by the WHO in 1999) are interpreted as taking just such a precautionary approach, and that social, economic, political and historic guidelines and factors are also important in in setting noise limits. The NPL report goes onto state that the WHO community noise guidelines (which influence the advice in BS 8233) have been interpreted as providing a conservative and precautionary approach to noise impact assessment. As they represent noise levels at which it is possible to start detecting effects and below which effects can be assumed to be negligible, and values exceeding the recommended noise levels are not necessarily indicative of significant adverse impacts. The NPL report comments furthermore that there is little evidence that the majority of the population exposed at the WHO Community Noise guideline noise levels would find them to be particularly onerous in the context of their daily lives.

Scrutiny of the latest WHO NNGs suggests that they are similarly precautionary and are commendably aimed at protecting the whole community including the most sensitive and vulnerable.

When using the WHO Community Noise guidelines or NNGs it is important to remember that, in seeking to provide guidance for the onset of health effects, the WHO necessarily takes a cautious approach. As shown above there are large variations in sensitivity to noise between individuals, so the WHO understandably is concerned with those who are the most vulnerable/sensitive/least tolerant. Consequently, their value as indicators of Statutory Nuisance are eroded, as the legally important tests include having regard only to persons who are ordinarily sensitive to noise and what is reasonable in the context of the nature and character of the locality

[152] Basner M, Uwe M, Griefahn G & Hume K, Evaluation of traffic noise effects on sleep, Institute of Acoustics Bulletin Vol 35 No 4, July/august 2010

[153] NPL Report CMAM 16: Health effect based noise assessment methods: a review and feasibility study; Nicole D Porter, Ian H Flindell & Bernard F Berry; NLP September 1998

Table 5 of BS 8233 provides an interpretation of the WHO Community Noise guideline noise levels by presenting a range of sound level values that are described as “good” and that reflect the current WHO guideline noise levels, to those that are 5 dBA higher and described as “reasonable” that are similar to the values from the 1980 WHO Environmental Health Criteria 12. BS 8233 qualifies its “good” and “reasonable” recommended noise levels by stating that normally only the upper value needs to be achieved (Section 7.3).

Taking all the above into account it is clear that where appropriate the WHO Community Noise Guidelines and the “good” values from BS 8233:1999 provide laudably high levels of protection from environmental noise and the reasonable values from BS 8233 provide better than satisfactory control. Consequently, where the guideline noise level values from the WHO Community Noise document and the “good” values of Tables 5 and 6 from 8233:1999 are not exceeded, then the level of acoustic protection can be regarded as being maximised as far as is justifiable in terms of the available research on environmental noise. Any uncertainty that unacceptable impacts may arise will have been minimised as far as is practicable. Indeed, it is also clear that where the guideline noise level values from the WHO Community Noise document and the “good” values of Tables 5 and 6 from 8233:1999 are exceeded, then significant adverse impacts are not automatically likely to occur, particularly if the reasonable levels from BS 8233 are not exceeded, until the noise levels are substantially higher than the WHO guidelines. However, it is important to remember that these values are based on environmental noise and the WHO and BS 8223 qualifications of the recommended guideline values from its community noise document i.e.

- That the recommended values apply to steady, constant and anonymous sources of noise,

  And:

- That in low background noise environments, values lower than those recommended may be needed.

Consequently where, like some forms of wind turbine noise, the signal is time varying and not constant, and/or occurs in an otherwise low background noise environment; the WHO and BS 8223 guideline values may not be appropriate.

5.6.7.1 Change Comparisons - Relative

Relative change comparisons are carried out by comparing specific sound levels before and after a development to describe the difference in specific sound level between the before and after situations.

Increases or decreases in relevant specific sound levels or other features are indicative of negative or positive noise impacts of the development respectively.

An example of this type of assessment is the assessment of road traffic noise impacts as described in the Department of Transport’s Design Manual for Road and Bridges Vol 11 (HA 13/08)[154].

The simple comparison of noise levels before and after a development is an attractive concept as it is relatively straightforward. However, there can be limitations to such an approach as although it can be suited to assessment of the impacts of changes in the noise level of a particular source, it is less well suited to assessment of the impacts of introducing a new noise source into an existing soundscape; especially where the new noise source has significantly different acoustic characteristics when compared to the existing soundscape.

[154] Design Manual for Roads and Bridges Volume 11 Section 3 Part 7 Traffic Noise and Vibration

Determining the simple numerical change of a particular noise indicator is only a starting point. When identifying the degree of noise impact, it is also necessary to consider, in qualitative terms, what might be the effect of any differences between the future and existing situations in either:

- the type of noise source, or
- the nature of the change, or
- other factors,

It is only by taking account of these factors that the degree of impact on noise sensitive receptors can be properly identified. The various other factors that have been identified as influencing this process are set out in the table below[155]:

Table 3: Assessment Factors

Factor	Issue
Averaging Time Period	Is the averaging time so long that it might mask a greater impact, or does the impact occur for only a small proportion of the time and can therefore be considered a smaller impact? To illustrate this problem, a quantitative assessment based on the change in the noise index, LAeq,16h shows an increase of about 1 dB(A) and the magnitude of impact may be classified as 'minor adverse'. However, this increase may have arisen where noise over 12 hours of the 16-hour period had not altered but there is an increase of approximately 5 dB in each of the remaining hours. In such circumstances, the impact may be re-assessed to 'major adverse', particularly if the increase occurred during the evening period when people are relaxing at home.
Time of Day / Night / Week	Is the change occurring at a time of day or night or period of the week e.g. weekend, which might cause a different impact? For residential properties, the evening and night periods may be regarded as more important, when most people are at home, whereas, the day period for schools is more relevant in assessing noise impacts. In addition to diurnal considerations there may be alternative periods which are relevant: • weekdays/weekends • Saturday/Sunday • weekdays/public holidays • seasonal effects
Nature of the Noise Source	Is there a change in the nature of the noise source which might alter the impact? Generally, a noise which is more variable or intermittent is regarded as more annoying or disturbing than a noise which is continuous over the same time period despite equivalent noise exposure levels,
Frequency of Occurrence and duration	How does the frequency of the occurrence of the noise and its duration affect the impact? The noise impact from a development which may include noise sources which do not occur every day may be dependent on the frequency and pattern of occurrences.

[155] Draft IEMA and IOA Guidelines for Noise Impact Assessment (2002 and subsequent re-drafts)

Factor	Issue
	For example 30 minutes emergency generator testing during the day on a week day once a week is likely to cause less disturbance than a routine operational noise of the same level for longer periods every day.
Spectral Characteristics	Is there a change in the spectral characteristics which might affect the impact? If a new noise source is expected to exhibit a very different frequency spectrum from the existing noise climate, the impact on disturbance may not be fully assessed from a simple difference in dB(A) noise levels. In BS 4142, when assessing industrial noise, distinct tonal content and other readily distinguishable acoustic characteristics are penalised by the addition of 5 dB(A) to the rated noise level. BS 7445 suggests a 3 to 6 dBA penalty for tonal noise depending on the tonality and/or impulsiveness of the noise
Absolute Level	How does the change relate to any applicable published guidance? Assessing the noise impact solely on the change in noise levels may give rise to gradual increases in noise as a result of a succession of small incremental increases in noise which individually may be regarded as insignificant, but cumulatively the overall increase may be significant. To address this problem the assessment should consider comparing absolute noise levels with recognised guideline target levels. A proposal which would cause an increase on an existing level which is already above an existing guideline should probably be regarded as worse than if the existing level were below the guideline. For an area recognised for its tranquillity or quiet, even a small increase is an impact which should be considered as a potentially significant because the specific amenity value of the location will be eroded.
Noise Metric	Has the change which would be heard been correctly identified? (i.e. has the correct noise indicator and averaging time period, T, been used?) are other supplementary noise metrics e.g. $L_{Amax,T}$ as well as L_{AeqT}, or additional non-acoustic data e.g. number of noise events also required to fully assess the impacts

Table 4 below sets out a scale describing a generic range of noise impacts on individuals in and around their homes.

Table 4: Generic Scale of (Adverse) Noise Impacts on Individuals in and around their home

Perception	Impact	Semantic descriptor	Significance (if required, particularly if the noise impact assessment is part of a formal EIA)
Not noticeable	None	No Impact	Not significant

Noticeable	Non intrusive Noise can be heard, but does not cause any change in behaviour or attitude, e.g. turning up volume of television; speaking more loudly; closing windows. Can slightly affect the character of the area but not such that there is a perceived change in the quality of life.	Slight	Generally not significant, but could be if the current acoustic environment is already poor
Noticeable	Intrusive (see note) Noise can be heard and causes small changes in behaviour and/or attitude, e.g. turning up volume of television; speaking more loudly; closing windows. Potential for non-awakening sleep disturbance. Affects the character of the area such that there is a perceived change in the quality of life.	Moderate	Significant
Noticeable	Disruptive (see note) Causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty in getting back to sleep. Quality of life diminished due to change in character of the area.	Substantial	Significant
Noticeable	Physically Harmful Significant changes in behaviour and/or and inability to mitigate effect of noise leading to psychological stress or physiological effects, e.g. regular sleep deprivation/awakening; loss of appetite, significant, medically definable harm, e.g. Noise induced hearing loss.	Severe	Significant

The draft IoA/IEMA guidelines on Noise impact assessment 2002 provides an example of a table of significance of changes in noise level, for sounds of a similar spectral and temporal nature and which are fairly constant and steady in level, which is reproduced below. Depending on the factors identified in table 3 above, the values in the noise change column and the semantic descriptors in the category column may vary for different noises in varying conditions from the examples shown in Table 3.

Table 5: Example of Categorising the Significance of Impact of the Basic Noise Change

Noise Level Change (dBA)	**Category**	**Significance**
0	No Impact	Not significant
0.1 - 2.9	Slight	Generally not significant, but could be if the current acoustic environment is already poor
3.0 - 4.9	Moderate	Significant
5.0 - 9.9	Substantial	Significant
10.0 and more	Severe	Significant

dB re 20 μPa

Note 1 It is important to beaware that a table similar to the above could have the same categories with different values of change in noise level and /or significance in circumstances including, where:

- The change is due to large changes in noise level of individual noise events, time averaged over a long period;
- The change is due to differences in the number or duration of noise events during a shorter phase of a longer time averaging period;
- The change is due to introduction of a new noise source with significantly different temporal and / or spectral characteristics to the existing soundscape;
- Established benchmarks of acceptable impact are already exceeded.

5.6.7.2 Context Comparisons - Relative

Context comparisons are carried out by comparing specific sound levels from a source against appropriate indicators of the pre-existing situation before the development takes place. Appropriate indicators of the pre-existing situation may include either or both the ambient and background sound levels. Examples of context comparisons might include comparing specific sound levels indicated by $L_{Aeq,T}$ against ambient or background sound levels indicated by the existing $L_{Aeq,T}$ or L_{A90T} noise levels respectively without the development.

The relationship between the specific sound levels corrected for characteristics which may make the noise more noticeable over the pre-existing noise levels are indicative of the possibility of negative impacts of the development.

An example of this type of assessment is the BS 4142:1997 - Method for rating industrial noise affecting mixed industrial and residential areas (and derivatives).

With BS 4142:1997 the measured background noise level ($L_{A90,T}$) is subtracted from the rating noise level of the noise in question, corrected for acoustic features which make it more noticeable. Paragraph 9 of BS 4142:1997 advises that as the difference increases, the likelihood of complaints increases.

The guidance relating to the measurement and assessment of industrial noise in BS 4142:1997: '*Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas' can be applied to plant noise and noise of an industrial nature*. This standard sets the following guidelines for assessing the likelihood of complaints based upon the difference between the measured background noise level and the rating level of the source under consideration, as shown in the Table 5.

Table 6: BS 4142 Assessment Criteria

Difference between Rating Noise Level & Background Noise Level	**Likelihood of Complaints**
Greater than +10 dB	Likely
+5 dB	Marginal significance
More than 10 dB below	Unlikely

dB re 20 µPa

The principal terms used in BS 4142 are broadly defined as follows:

- Specific noise – the noise source under consideration
- Rating level – Residual noise corrected to allow for certain distinctive acoustic features
- Residual noise – the ambient noise remaining when the specific noise is sufficiently suppressed so as not to contribute to the ambient noise level
- Background noise – the measured L_{90} level of the residual noise

It is important to remember that the forward to BS 4142 states that the absolute level of noise and a range of non-acoustic factors are important, as well as the relationship with any underlying noise levels, in determining the noise impact.

One of the main drawbacks of relative context comparisons is the establishment of the pre-existing situation before the development takes place: or for existing operations the question arises is it the background noise level with the plant or operation being altered running (as it is part of the existing soundscape), or with only the plant or operation being altered not running but other operations at the site under way, or is it the background noise level with all the plant and activity at the site in question turned

off? Additionally, the establishment of the specific sound levels to compare with the background noise level can be difficult as there may be a multitude of other noise sources associated with the relevant site or nearby and no break in the noise emitted by the site or other sources in which to accurately measure any the specific noise level of the activity under investigation or the underlying background noise level. Another problem that can arise is that the background noise level after implementation of a scheme may not be the same as before hand, in which case such an assessment risks under or over-estimating the impacts once the scheme is in place.

One problem with BS 4142 is that it seeks to predict the likelihood of noise complaints, rather than assess the impacts of noise; and the standard itself specifically advises that it is not a means of determining nuisance.

Additionally there is a specific drawback with BS 4142, as it should not be used in low background noise environment i.e. below 30 dB $L_{A90,t}$ or where the rating noise level is less than 35 dB $L_{Aeq,t}$. Background and rating noise levels as low and lower than these are not uncommon in rural areas; thereby disqualifying use of the standard from these circumstances. However, BS 7445 – Description and measurement of Environmental Noise provides a similar approach to BS 4142, but has no limitation on it's use in low noise environments.

5.7 Cumulative Impacts and Nuisance

5.7.1 Cumulative impacts

As the number of wind farms increase across the UK the situation where a receptor is exposed to noise from more than one wind farm is likely to arise more frequently.

ETSU-R-97 makes in plain that it is unreasonable for wind farm developers to use the "creeping background" effect of incrementally small increases in noise from successive wind farm schemes to increase the noise limits they have to comply with. Instead developers of successive schemes are meant to use the background noise without the contribution of any existing wind farm scheme as the baseline for their proposal i.e. the noise limits set at a receptor by the first scheme apply to the cumulative impacts of any successive scheme as well. Typically this can mean that the where the first scheme noise levels are near the maximum permitted, the noise levels from any subsequent scheme will have to be 10 decibels below those of the established scheme to avoid breaching the existing limits.

Determining the underlying noise levels at a property that may not have been considered in the ES for an existing scheme, but which may be affected by the cumulative impacts of the existing development and a new scheme is not easy. Essentially there are three methods e.g.

1. Use data from the ES for an existing scheme as a proxy for the new location; or,
2. Measure noise levels at the potentially cumulative impacted premises and deduct the predicted noise from each of the schemes that may affect it; or,
3. The developer of the new scheme compensates the owner of the old scheme for turning their turbines off for long enough to carry out a noise survey uninfluenced by the noise of the existing scheme.

None of the three methods is ideal, method 3 is often impracticable, but a combination of methods 1 and 2 can be useful.

Increased "nuisance" due to noise from the cumulative impacts of existing and proposed wind farms was part of the reason given for the refusal of a planning appeal in regard to a wind farm at Gorsedd Bran in Denbighshire in North Wales[156]. The inspector accepted that although ETSU-R-97 limits would not be breached with the new scheme, there would be increased noise, particularly on days when currently the wind direction meant the residents heard no wind farm noise from existing schemes and that there would

156 Appeal Ref: APP/R6830/A/08/2074921, Gorsedd Bran, Nantglyn, Inspector Stuart B Wild.

be an increase in nuisance to the residents (in a letter after his decision the inspector stated he was using nuisance in its normal colloquial sense rather than as a legal term).

The developer appealed this refusal and at the High Court Justice Mr Gwyn Williams[157] overruled the planning inspector's decision on the basis that the Inspector's conclusions and use of the term nuisance indicated he had come to an unreasonable decision; as he had not explained in detail how noise levels below ETSU-R-97 guidelines would be unacceptable. Consequently the judge found that the inspector had not adequately explained of his reasons for his conclusions on noise and therefore quashed the refusal of planning permission. Central to Justice Williams reasoning was the view that it was '*irrational*' to find that the development would comply with the ETSU-R-97 guidelines, as supported by TAN 8, but would still be objectionable.

However, the local planning authority appealed the High Court's decision to the Court of Appeal, where it was common ground that the noise from the proposed development, whether considered individually or cumulatively, would not exceed the levels set out in ETSU-R-97. However, the local planning authority argued that an alternative method of assessing noise should be preferred and a group of local residents argued that, regardless of the levels which ETSU-R-97 regarded as a sufficient protection of their amenity, the existing wind farm was causing what they regarded as a 'nuisance'. Their fear was not so much that a further development would mean that there was an increase of noise as such but, rather, that a new development in a different place would mean that whereas there are now times when there is no noise audible because of wind direction, if the Gorsedd Bran scheme were to be built there would usually (or at least more regularly) be some noise because of the prevailing wind direction. In a nutshell, the Court of Appeal felt that their objections could be summarised as '*Enough is Enough'*. The Court of Appeal highlighted that the use of ETSU-R-97 in Wales was only "*good practice*" under the terms of TAN 8[158]. Consequently the Court of Appeal agreed that the Inspector was entitled to agree with the residents that "*enough was enough*" even though ETSU-R-97 limits would not be breached, and overturned the High Court judgment and upheld the Inspector's decision to refuse planning permission[159]

[157] Tegni Cymru Cyf vs the Welsh Ministers & Denbighshire county council [2010] EWHC 1106 (Admin)

[158] Similarly for Scotland where guidance describes ETSU-R-97 as "*relevant guidance on good practice";* whereas in England local authorities are advised that they "should" use ETSU-R-97 by PPS 22 and its companion guide).

[159] A more detailed examination of this case can be found at http://www.39essex.co.uk/docs/news/tegni_cymru_cyf_v_welsh_ministers.pdf (Last viewed 5th April 2011)

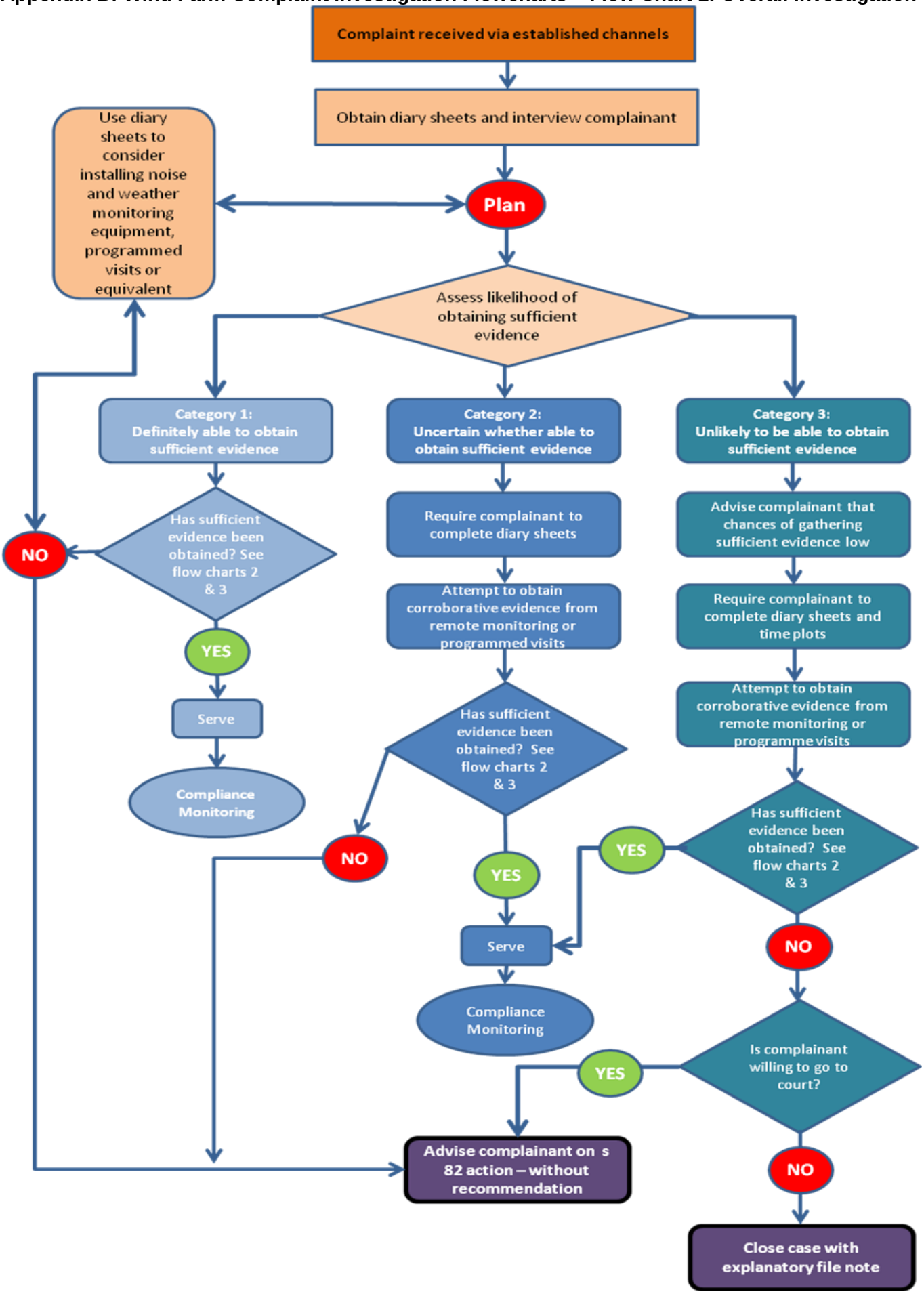
Appendix A: Glossary of Terms

Amplitude Modulation of Aerodynamic Noise (AM)	The variation of level in time of the aerodynamic noise of a wind turbine
Ambient Noise	Totally encompassing sound in a given situation at a given time composed of sound from all sources near and far.
Anemometry Mast	A mast on which fixed equipment (including an anemometer) is erected to measure the wind speed and wind direction over a particular site. They are usually fixed to the ground with guy wires.
Background Noise	Is the ambient noise, in the absence of the noise under investigation, measured using time weighting "F", that is equalled or exceeded for 90% of the measurement time interval. Expressed as $L_{A90,T}$, where "T" refers to the measurement time interval in minutes.
BPM	Best Practicable Means Only a court may ultimately determine what constitutes 'best practicable means' in each individual case. *BPM can be cited as a ground for appealing against an abatement notice served under s80 of the Environmental Protection Act 1990. Furthermore, BPM is available as a defence in prosecution for non-compliance with the terms of any such notices.* *BPM is defined in both the Control of Pollution Act 1974 and the Environmental Protection Act 1990 and encompasses the following features:* • *'practicable' means reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications;* • *the 'means' to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery and the design, construction and maintenance of buildings and structures;* • *in circumstances where a code of practice for noise minimisation is applicable, regard shall also be had to guidance given in it.*
dBA	The noise level in decibels, a measure including a correction for the sensitivity of the human ear defined in the International standard IEC61672:2003 and various national standards relating to the measurement of sound level.
De-Commissioning	This is the final phase of the development when the site is cleared of above ground equipment associated with the wind energy project and the land restored to its original use or some other agreed use.
EHP	Environmental Health Practitioner
Emission Level	This is a measure of sound emitted by a given source.
Energy Yield	This is the term to describe the electrical output from a wind energy project. It is strongly influenced by the wind speeds associated with a site.
Equivalent Continuous Level $L_{Aeq,T}$	This is the steady notional sound level which contains the same acoustic energy over a specified time period as the actual time varying sound, measured in dBA. It represents in a single figure the **average** noise level of the actual varying noise level over the defined time interval (T).
Hub Height	The height of the wind turbine tower from the ground to the centre-line of the turbine

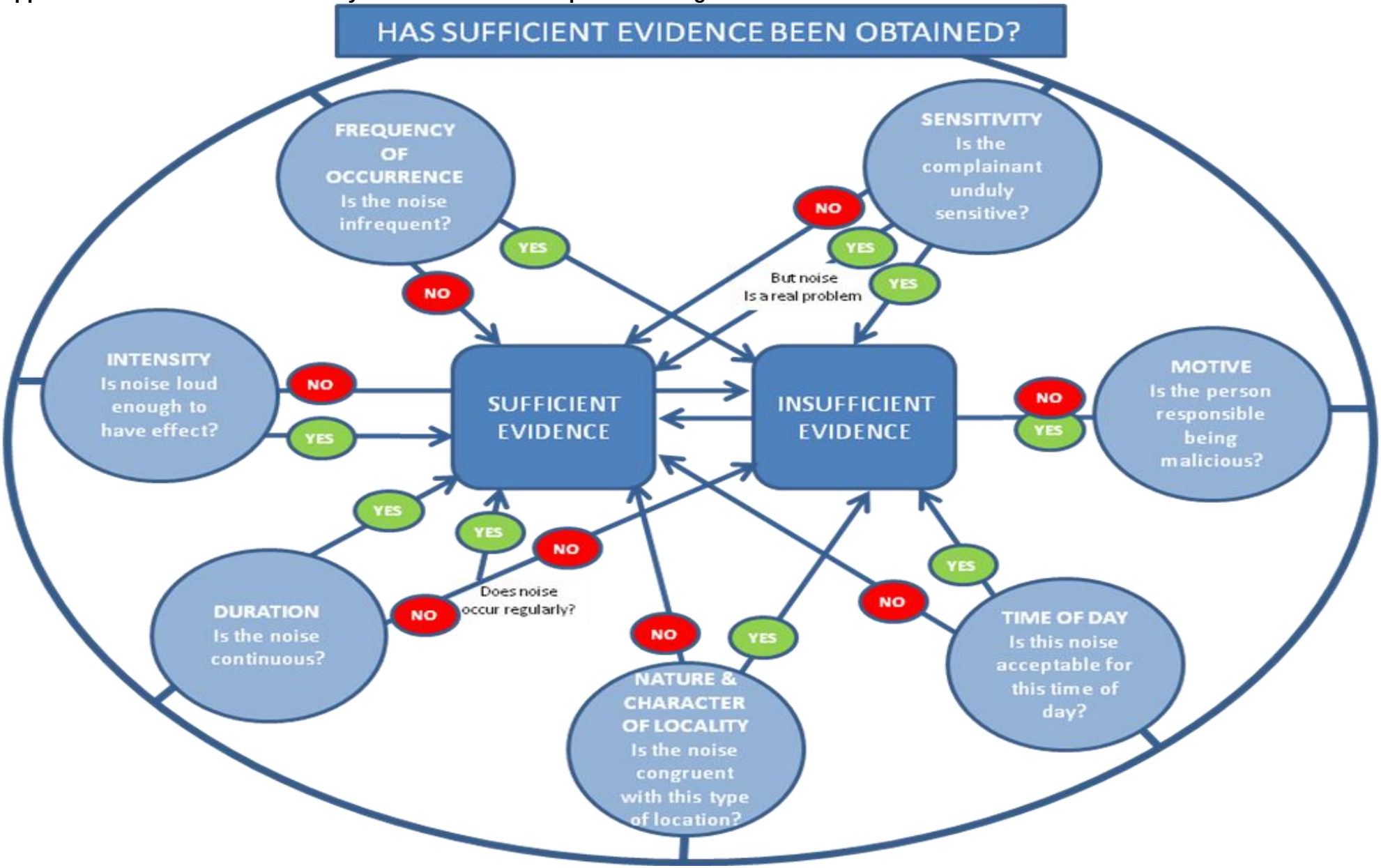
	rotor.
Turbine Noise Immission Level	The incident noise level only to the wind turbine expressed as $L_{A90,10min}$ attributable at a specified receptor location
Impulsive Noise	An impulsive noise is characterised by its short duration and sharp rise and decay and would generally exhibit broadband spectral content
Infrasound	This is sound at frequencies below about 20 Hz (see also Low Frequency Noise).
Inter-rater Comparisons	Consistency between interviewers
Low Frequency Noise	This is sound below a frequency of about 100 to 150 Hz, especially in the 40-60 Hz range. Compared with sound of mid and high frequencies, low frequency sound is much less attenuated by passage through air or by passage over acoustically soft ground such as grassland. Low frequencies can thus become more prominent at greater distances.
Maximum Sound Pressure Level ($L_{Amax,T}$)	This is the maximum recorded sound pressure level within the relevant time interval (t).
Noise	This was defined in the Wilson report published in 1963 as 'unwanted sound'. Noise includes vibration, except where the context indicates otherwise. Sound is a periodic fluctuation in pressure, typically in air. Noise is classified as a pollutant in the European Directive on Integrated Pollution Prevention and Control.
Noise Sensitive Location (Receptor)	Any dwelling, hotel or hostel, health building, educational establishment, place of worship or entertainment, or any other facility or area of high amenity, which may be susceptible to noise.
Noise Source	Premises at which an activity or process is undertaken that results in the emission of noise.
Prevailing Background Noise Level	The background noise level derived from regression analysis of the background noise data.
Scoping Document	This document establishes the full scope of the environmental assessment and should be agreed in writing with the local planning authority.
Shadow Flicker	Under certain combinations of geographical position and time of day, the sun may pass behind the blades of a wind turbine and cast a shadow. When the blades rotate, the shadow flicks on and off. The effect only occurs inside buildings where the flicker appears through a window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the site.
SIANCE	'Standardised Interview to Assess Domestic Noise Complaints and their Effects' (SIANCE) Final Report December 2000.
Stakeholder	Put in its simplest terms, anyone with an interest in the subject, be they customer, consumer, provider or enthusiast (prospective influencer) can be considered to be a stakeholder,
Statutory Nuisance	Statutory nuisance is an act or omission which has been designated a nuisance by parliamentary statute and this includes noise.
Tonal Noise	Noise can be described as tonal if it contains a noticeable or discrete, continuous note. This includes noises such as hums, hisses, screeches, drones, etc. and any such subjective description is open to discussion when reported.
Ultra Vires	An action outside the proper authority or purposes of a corporation or corporate

	officer. (Latin for ‘Beyond the Power’)
Wind farm	A group of Wind Turbine Generators installed in the same region and all operated by the same operator.
Wind Shear	A description of the increase in wind speed with height above ground level
WTG	Wind Turbine Generator.

Appendix B: Wind Farm Complaint Investigation Flowcharts – Flow Chart 1: Overall Investigation



Appendix C: Wind Farm Statutory Noise Nuisance Complaint Investigation Flow Charts – Flow Chart 2: Nuisance Limb



Appendix D: Wind Farm Statutory Noise Nuisance Complaint Investigation Flow Charts – Flow Chart 3: Prejudicial to Health Limb