Environmental Protection Agency
Office of Environmental Enforcement (OEE)

Guidance Note on Noise Assessment of Wind Turbine Operations at EPA Licensed Sites (NG3)

June 2011

Acknowledgements

This guidance note has been prepared on behalf of the Environmental Protection Agency by:

- Ms Sinéad McAleer, Fehily Timoney and Company
- Dr Andrew McKenzie, Hayes McKenzie

The following EPA staff were involved in the review of this guidance note:

- Mr Tony Dolan
- Dr Ian Marnane
- Mr David Flynn
- Ms Maria Lenihan

together with Mr Tony Clayton of the UK Environment Agency.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS - Cont'd...

Page

LIST OF APPENDICES

LIST OF FIGURES

PAGE

LIST OF TABLES

EXECUTIVE SUMMARY

The Environmental Protection Agency has developed a Noise Guidance Note (NG3) to assist waste licensed and integrated pollution prevention and control (IPPC) licensed sites in assessing the suitability of their sites for wind energy development. This guidance note is the third in a series of Noise Guidance Notes published by the Agency and is designed to provide the relevant knowledge and guidance to licensees together with their consultants, regulators and third party developers.

The focus of this document is the development of a standardised noise impact assessment methodology to allow sites to assess the impact of wind energy proposals on noise sensitive locations. The methodology provides technical information on assessing and measuring noise in order to ascertain compliance with the proposed limits.

The essential points of this guidance document relate to:

- Descriptions of the salient points of wind power generation, wind turbines and wind turbine noise
- Review of relevant planning legislation, guidance and standards
- Specified noise prediction methodology
- Proposed daytime (08:00 to 22:00 hrs) and night-time (22:00 to 08:00 hrs) cumulative noise limits for combined site and turbine noise

Proposed Cumulative Site and Turbine Noise Limits:

- Daytime 55 dB $L_{Ar,T}$
- Night-time 45 dB L_{Aeq}
- Wind turbine noise not to exceed 45 dB L_{Aeq} at any time, or to contain any significant tonal components

- Where predicted cumulative noise does not comply with the standard noise limits above, an application can be made to the Agency to seek an increase based on measurements of site specific background noise levels
- Standardised noise impact assessment methodology including measurement and monitoring requirements
- Standardised templates for providing data analysis, noise predictions and compliance assessments to the Agency

PREFACE

Introduction to Environmental Protection Agency

The Environmental Protection Agency (EPA) administers a wide range of licensing, enforcement, assessment and monitoring activities. The Office of Environmental Enforcement (OEE) operates under the control and direction of the Board of the EPA dedicated to the implementation and enforcement of environmental legislation in Ireland.

The OEE's main functions are to:

- Improve overall compliance with environmental protection legislation
- Raise awareness about the importance of enforcement of environmental protection legislation
- Enforce Integrated Pollution Prevention and Control (IPPC) licences and waste licences
- Audit and report on the performance of local authorities in their environmental protection functions, including:
    - Prosecute, or assist local authorities to prosecute, significant breaches of environmental protection legislation, in a timely manner
    - Assist local authorities to improve their environmental protection performance on a case by case basis, through establishing an enforcement network to promote information exchange and best practice, and by providing guidance

The OEE approach seeks to provide information and advice via guidance to those it regulates to ensure environmental improvements while ensuring value for money[1].

Existing Noise Guidance Notes

The Agency has released two noise guidance notes to date. The first in 2003, 'Environmental Noise Survey Guidance Document'[2], provided advice on conducting a noise survey in accordance with noise conditions laid out in IPPC and waste licences. The second guidance note, 'Guidance Note for Noise in Relation to Scheduled Activities, 2nd Edition'[3], was released in 2006 providing an update on changes to legislation, licensing requirements and Agency policy.

Purpose and Objectives of this Guidance Note (NG3)

The noise guidance notes previously released by the Agency provide for standard noise monitoring and assessment of industrial noise. The noise impact from wind turbines is different to standard industrial noise as it has varying noise levels with wind speed, and it also varies in relation to monitoring requirements. To assess turbine noise, one needs to understand how turbine noise is generated, and the differences in how it needs to be assessed.

The objectives of this guidance note (NG3) are to provide:

- guidance on assessing the potential noise impact on noise sensitive locations (NSLs) from wind turbines on EPA licensed sites
- a noise impact assessment methodology to ensure that all data generated is reliable and that the recommendations are fully justifiable

This noise guidance document (NG3) is intended to allow IPPC or waste licence holders to determine if their own sites are suitable for wind turbine development with respect to noise nuisance. This noise suitability assessment should include a licensee's historical noise compliance with licence conditions. If the assessment shows that there is a potential for noise nuisance to be caused, the licensee should consider opportunities for noise mitigation to negate noise nuisance impact or reconsider the suitability of the proposed turbine locations, or site, for such a development.

This note should be read in conjunction with the Environmental Noise Survey Guidance Document (2003) and the Guidance Note for Noise in Relation to Scheduled Activities (2006).

Highlighted terms throughout the text are provided with definitions in the Glossary (Section 10).

Revision of Document

This guidance note may be subject to review or amendment. The EPA website (www.epa.ie) will maintain the most up to date version of this guidance note. Please contact Tony Dolan (t.dolan@epa.ie) with any queries.

Disclaimer

This guidance note, and particularly the templates contained in the Appendices, represents the authors' judgement of the best available techniques and practices for noise measurements and predictions. As such, it may not cover all situations and it may be necessary to employ variations to the methods described in this note by agreement with the Agency.

1. INTRODUCTION

This guidance note has been developed and written for a wide range of users. These include licensees, regulators, Agency inspectors, acoustic professionals, planners and third party developers (i.e. companies providing design and build autogeneration schemes for sites). Figure 1 overleaf highlights which sections are of most relevance to each user. It is, however, recommended that the entire document is reviewed to ensure a comprehensive understanding of turbine noise and its implications for licensees.

1.1 Noise Conditions in EPA Licenses

It is a requirement of the Environmental Protection Agency to ensure that licensed sites (IPPC[i] licence and waste licence) do not cause unacceptable impact on the environment which includes noise impact on the human environment. IPPC and waste licences contain several conditions in relation to noise including separate daytime and night-time noise limits, monitoring and reporting protocols and site specific noise monitoring locations. It is the responsibility of each licensee to ensure that the site is compliant with these conditions and does not have a detrimental effect on the local noise climate. IPPC and waste licences may also contain conditions to control site noise and the resultant noise impact. The overriding objective is to minimise or negate noise impact at **noise sensitive locations** (NSLs)[ii].

1.2 Description of Guidance Note Sections

Section 2 Ireland's Commitments to Alternative Energy discusses the rationale behind the promotion of alternative energy in Ireland and future commitments to alternative energy including wind energy, and the potential benefits of wind farm operations.

Section 3 Wind Turbine Operations and Noise describes wind turbine operations including required site infrastructure.

Section 4 Potential Noise Impacts of Wind Turbine Operations identifies the typical impacts of wind turbine operations.

Section 5 Planning Legislation and Requirements provides licensees with a brief explanation on the planning requirements for applications to construct wind turbines including the interaction of the planning process with the Agency.

Section 6 Noise Guidance, Standards and Legislation details the adopted legislation and standards in Ireland, the UK and other European countries governing noise from wind turbine operations and the advantages and disadvantages of the differing approaches which are used.

Section 7 Noise Limits describes how noise limits are applied to Agency licensed sites with wind turbine operations and how the noise limits for turbine operations will interact with existing noise limits.

Section 8 Noise Impact Assessment Methodology describes how a site should assess compliance with the noise limits determined in Section 7.

[i] Integrated Pollution Prevention and Control

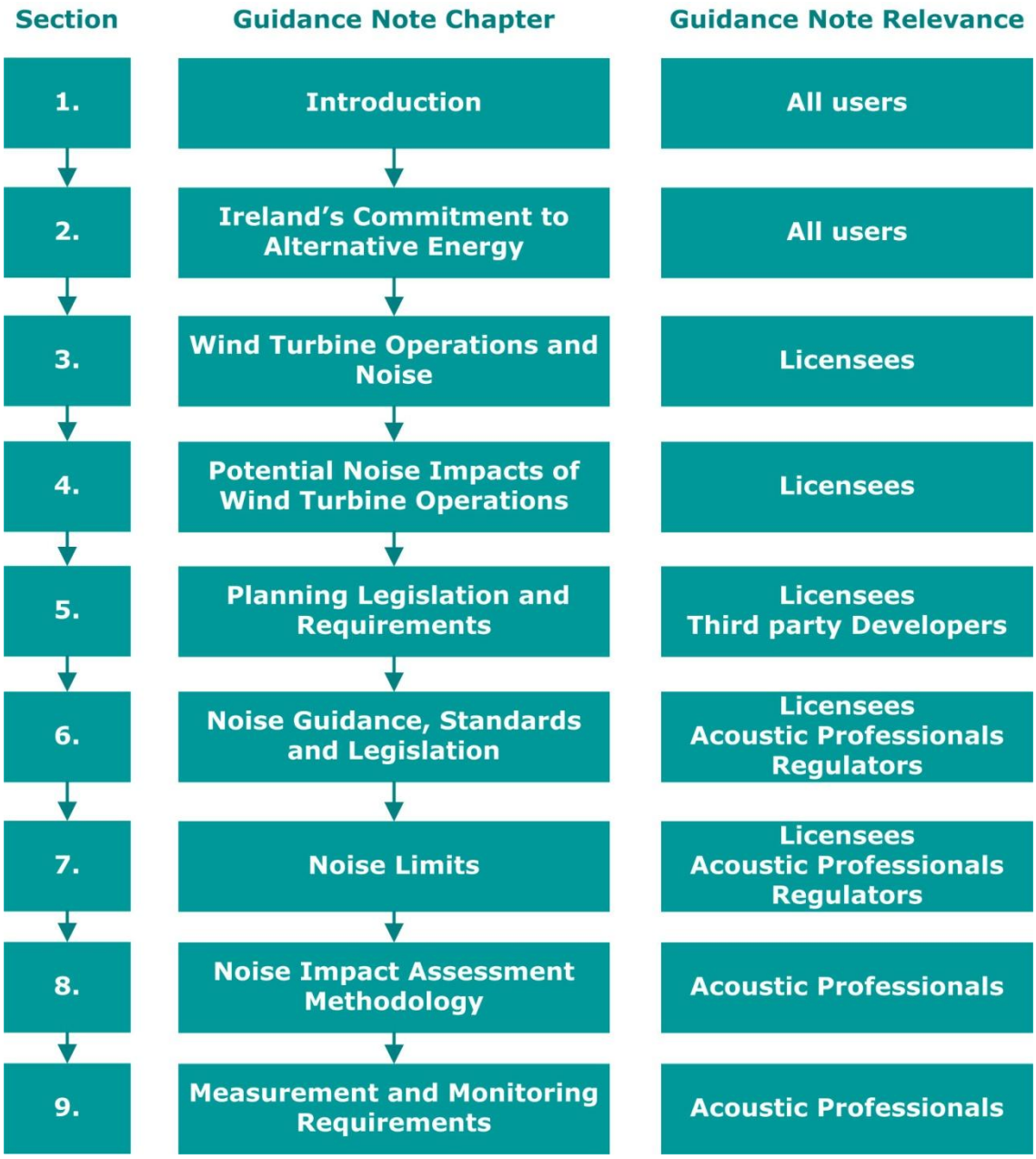
[ii] Any dwelling house, hotel or hostel, health building, educational establishment, place of worship or entertainment or any other facility or other area of high amenity which for its proper enjoyment requires the absence of noise at nuisance levels

Details are provided on specific requirements for wind turbine modelling such as the acceptable modelling standard, modelling parameters, and acceptable sources of turbine sound power data. Templates are provided in the appendices which allow for a standardised assessment methodology to be submitted to the Agency for approval.

This will reduce the Agency's time needed to assess all applications and ensure that the entire assessment is transparent, straightforward to apply by the applicant and straightforward to assess by the Agency.

Section 9 Measurement and Monitoring Requirements: describes the noise monitoring protocols to be employed for licence compliance measurements by licensees or their appointed noise specialists.

Figure 1: Quick Reference to Guidance Note



2. IRELAND'S COMMITMENT TO RENEWABLE ENERGY

2.1 European and Irish Renewable Energy Targets

2.1.1 European Renewable Energy Targets

The EU Directive on Promotion of the Use of Energy from Renewable Sources (2009/28/EC)[4] was implemented in December 2008. It establishes the goals for 2020 of achieving 20% EU energy consumption from renewable sources and a 20% cut in greenhouse gas emissions - the 20:20:20 plan. This Directive recognises the need to promote renewable energy sources (RES) and technologies which will have a positive impact on:

- security of energy supply
- regional and local development opportunities
- rural development
- export prospects
- social cohesion
- employment opportunities

The promotion of electricity produced from RES is a high EU priority.

Under an EU "burden sharing" arrangement, Ireland's overall national target for the share of RES in gross final consumption of energy in 2020 is 16% (increased from 3.1% in 2005)[5].

In the last 5 years, Ireland has progressed in accelerating renewable energy generation. The 2001 Directive on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market (2001/77/EC)[6] set Ireland a target of moving from 3.6% electricity from RES to 13.2% by 2010, which has been exceeded. It is currently anticipated that Ireland's EU renewable energy target will be met.

2.1.2 Irish Renewable Energy Targets

Irish renewable energy targets are fully commensurate with the European Union's energy policy objectives and the targets attributed to Ireland under the Renewable Energy Directive, as set out in Table 1 below.

Table 1: Irish Targets for Renewable Energy[7]

Share of Renewable Energy Consumption	EU Target
RES-Electricity	40%
RES-Heat	12%
RES-Transport	10%

The Government has set a target of 40% RES-Electricity by 2020, with an interim target of 15% by 2010, which has already been exceeded. The significant growth in electricity from renewable sources in recent years is largely attributable to onshore wind.

2.2 Current Irish Wind Energy Capacity

1,680 MW of wind energy is currently installed in Ireland (May 2010), generated from over 143 wind energy developments in 25 counties[8]. 1,258 MW is contracted to be commissioned between May 2010 and Dec 2012 (as of June 2010)[9].

The third and latest Commission of Energy Regulation's grid connection offers (Gate 3) will cater for an additional 3,990 MW wind farms (as of July 2010)[10].

The combination of installed projects, contracted wind farms, and Gate 3 offers will comprise 40% of Ireland's electricity generation capacity[11]. There are a further 11,158 MW in the queue for grid connection offers beyond the Gate 3 process.

The Irish Wind Energy Association estimates that 8,250 MW of wind energy will be installed in Ireland by 2020, incorporating 2,000 MW export capacity to the UK.

Plans for the situation beyond 2020 are currently being examined. It is likely that development beyond Gate 3 could be strongly linked to the potential for electricity export, and to the UK and possibly other interconnectors, as well as to the potential for developing electric vehicles.

A significant level of wind energy currently has planning permission in Ireland, and is awaiting construction. Some of this capacity is contracted for grid connection, or in the Gate 3 process, and some is in the post-Gate 3 queue. Not all the contracted or Gate 3 wind farm projects have planning permission.

2.3 Benefits and Disadvantages of Wind Energy

The development of renewable energy is central to overall energy policy in Ireland as described in Section 2.1. Renewable energy improves security of supply, reduces dependence on fossil fuels, and reduces greenhouse gas emissions.

At a more local level, there may be opportunities for industries to develop wind energy through auto-production, where a suitable site is available. This has the primary advantage of reducing power costs, while simultaneously improving the carbon balance, and providing a strong signal of a company's commitment to sustainable development.

Wind energy generation does come with negative impacts such as the potential for effects on landscape, fauna and airborne signals such as television reception and impacts on the human environment which includes the impact of noise generation from turbines and **shadow flicker**. It is a requirement of the Agency to ensure that licensed sites do not cause injurious effects on the environment and this guidance note (NG3) is designed to specifically address the impact of noise on the human environment.

3. WIND TURBINE OPERATIONS AND NOISE

3.1 How Wind Turbines Work

Typical modern turbine design incorporates tubular towers with three blades connected to machinery inside an enclosure at the top of the tower called the **nacelle**.

The wind turns the blades which spin a shaft, which connects to a generator, usually through a gearbox, which generates electricity. An example of a typical turbine is presented in Figure 2.

The rotor blades are generally made of fibre glass reinforced plastics. These are bolted to the central hub at the top of the tower. This hub is connected to the nacelle, which houses the gearbox (where required), generator, electrical components and control unit of the turbine. A turbine control unit is at the base of the tower. An internal ladder leads up to the nacelle. Earthing and isolation protect all components from lightning strikes.

Turbines of this size typically turn at 9 to 25 revolutions per minute depending on wind speed and type of turbine.

Stall regulated turbines are also available but are less commonly used than pitch regulated turbines. Rotor blades on stall regulated turbines are bolted at a fixed angle which allows the blades to stall when the wind speed becomes too great.

Pitch regulated turbines can pitch (turn) the rotor blades when the wind changes to ensure that the energy generation is optimised. The advantage of a pitch regulated turbine is that it allows for maximum output at all operating wind speeds but requires detailed engineering to enable this to occur. While stall regulated turbines have simpler mechanisms (because the rotor blades are at a fixed angle), they do not generate electricity as optimally as pitch regulated turbines.

Figure 2: Typical Turbine

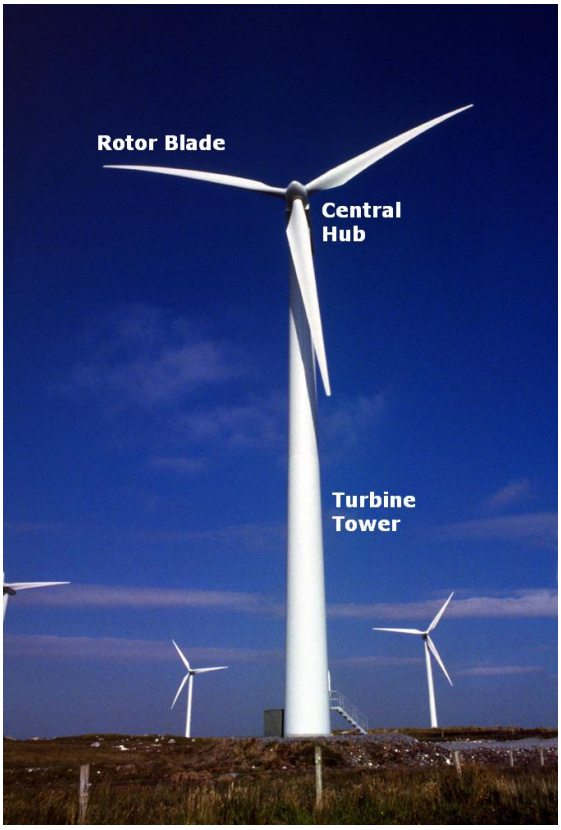
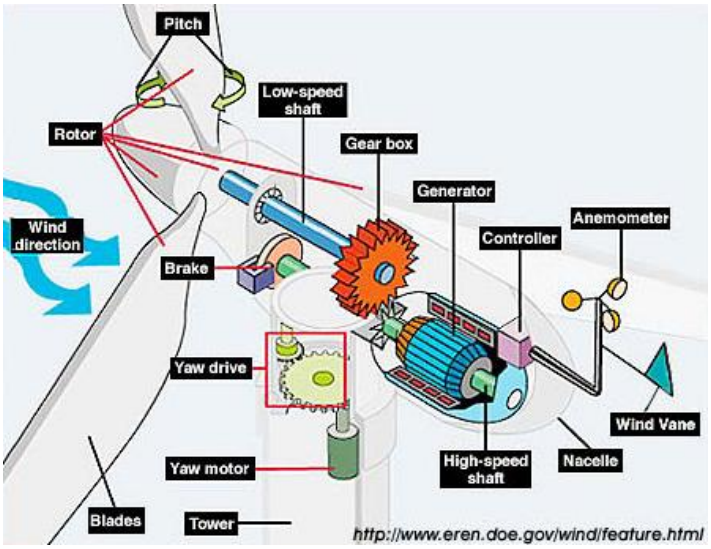


Figure 3: Typical Nacelle



3.2 An Introduction to Noise and Noise Terminology

Noise is defined as unwanted sound and can range from high levels (causing physical damage) to levels only just audible. Noise is measured in decibels (dB), and human hearing ranges from approximately 0 dB (the threshold of hearing) to 120 dB (the threshold of pain). A change of 3 dB in noise level is just perceptible under normal circumstances and results from doubling or halving the number of noise sources. A change of 10 dB corresponds to an approximate doubling of perceived loudness.

The way a noise sounds is partially determined by its pitch or frequency, which is measured in Hertz (Hz). Human hearing covers frequencies from 20 Hz to 20,000 Hz and is less sensitive at low and high frequencies. Because the ear is less sensitive at low and high frequencies, this has to be allowed for in noise measurements by reducing the response of measurement equipment by a similar amount. Various 'weightings' to measurements of sound pressure level are available for this purpose, and the 'A' weighting is the one which is normally used for environmental noise measurement, as it appears to correlate best with human subjective response, with the resulting weighted noise levels referred to as being in dB(A). Sounds which cover a range of only a few Hz are referred to as being **tonal**. Sounds which cover a wide range of frequencies do not have any tonal character and are referred to as being **broadband,** i.e. not dominated by any particular frequency.

Most noise is not steady but varies over time. As a result, statistical averaging is used to quantify noise levels over a given time period. For instance, the $L_{Aeq,T}$ is a measure of the average noise over a 'T' measurement period such as $L_{Aeq,10min}$ represents the ('A' weighted) average noise level over a 10 minute period.

Percentiles are typically used to describe noise level over a percentage of the measurement period such as the $L_{A90,T}$ which is the noise level exceeded for 90% of a 'T' measurement period and $L_{A10,T}$ which is the noise level exceeded for 10% of a 'T' measurement period. These can be used to express a range of descriptive percentiles from L_{A1} to L_{A99}. $L_{A90,T}$ is normally used to describe '**background noise**'.

3.3 Noise Emissions from Wind Turbines

3.3.1 Mechanical Noise

Like any piece of equipment containing moving parts, a wind turbine emits a certain amount of mechanical noise. This is generally dominated by noise from the gearbox (although not all turbines have gearing systems) and, to a lesser extent, the generator. There may also be noise from cooling fans, oil pumps and other auxiliary equipment. In addition, the **yaw** motors make occasional noise as they turn the turbine to face into the wind.

As for all rotating machinery, associated mechanical noise may have **tonal** components which generate noise with a specific pitch dependant on the speed of rotation. Where it occurs it can have a significant effect on the way the resultant noise is perceived. A noise with a significant tonal component is likely to give the impression of a noise which is 5 dB or louder than a noise of the same level without any tonal component.

Modern wind turbine design incorporates insulation in the nacelle to prevent airborne transmission of mechanical noise. Nacelle isolation is also incorporated to prevent vibration from moving parts being transmitted into the tower or blade assemblies and subsequently re-radiated as structure-borne noise.

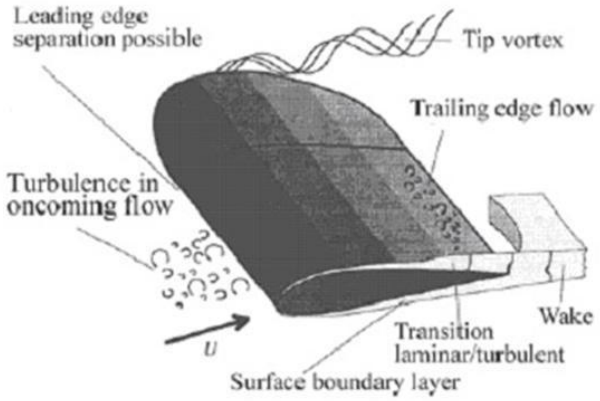
This has become the norm over 20 years of commercial wind turbine operation in Ireland such that it is now unusual for ***tonal components*** to be a significant factor in wind turbine noise. However, tonal components continue to be regulated by planning conditions which include a penalty for such effects. Standard ISO 1996 'Acoustics – Description, measurement and assessment of environmental noise Part 2:2007 Determination of environmental noise levels' provides for tonal assessment and penalties.

Tonal components should likewise be covered within manufacturers test data and warranty documents. It should be noted that typical Agency licences prohibit tonal noise at night and apply a penalty during the day.

3.3.2 Aerodynamic Noise

Although rotational speed of modern wind turbines is relatively slow at around 20 revolutions per minute, the speed at which the tips of the blade travel can be fairly high due to the length of the blades. The equivalent tip speed for a 90 metre blade diameter turbine would be 340 km/hr; approaching the speed of sound. As a result, **aerodynamic noise** from large wind turbines can be fairly significant and, due to improvements in the control of mechanical noise, is now the more dominant noise source. The sound is broadband, and may be likened to the noise of rushing water. It can be controlled to a certain extent by careful blade design to minimise vortex shedding from the blade tips and trailing edge noise where the flow over the two sides of the blades interacts. It is inevitable that there will be a certain amount of residual noise from where the boundary layer separates from the blade surface and from where the turbulent incoming airflow meets the leading edge of the blade.

Figure 4: Generation of Aerodynamic Noise



3.3.3 Noise Characteristics

General

In general, noise from wind turbines increases with wind speed and rotational speed. Most modern wind turbines are pitch regulated variable speed turbines which have a characteristic noise profile of steeply increasing noise with wind speed up to the point at which the turbine is generating its '**rated power**' or maximum power above which there is usually no increase in noise. For 'stall regulated' machines, noise can increase considerably above rated power of the turbine and such designs are becoming less popular as a result.

Spectral Characteristics

The aerodynamic noise is broadband and spread across the audible frequency range. There is a common misconception that there is a significant component of low frequency noise but this is not the case. As distances increases from a noise source, the noise spectrum becomes more biased towards the low frequencies. This is caused by greater attenuation of middle to high frequencies by atmospheric effects, with reduced attenuation of low frequencies.

This is true of any broadband noise such as road traffic or the sound of the sea. This may, therefore, be a significant characteristic for a large wind farm site when heard from a distance although close to the turbines, it would not be significant.

There is similarly no significant **infrasound** from wind turbines. Infrasound is high level sound at frequencies below 20 Hz. This was a prominent feature of passive yaw 'downwind' turbines where the blades were positioned downwind of the tower which resulted in a characteristic 'thump' as each blade passed through the wake caused by the turbine tower. With modern active yaw turbines (i.e. the blades are upwind of the tower and the turbine is turned to face into the wind by a wind direction sensor on the nacelle activating a yaw motor) this is no longer a significant feature.

Tonal content in the noise, where it occurs, can be identified by peaks in the frequency spectrum and quantified according to recognised procedures dealing with the audibility of tonal components in broadband noise such as ISO 1996 Part 2:2007. As before, it is uncommon for wind turbine noise to contain tonal components but these can be minimised through insulation and isolation as discussed above.

Temporal Characteristics

Wind turbine noise fluctuates at a rate depending on the speed of rotation. Technically this is known as **amplitude modulation**, which means variation in noise level, although it is sometimes referred to as **aerodynamic modulation** or **blade swish**. This feature of amplitude modulation can readily be observed close to a single wind turbine such that on the downward stroke a different level and timbre of noise may be heard to that as it passes the tower, or as occurs on its upward stroke. As distance from the turbine increases this effect reduces although for some configurations of turbine sites the effect has been noted to be audible at residential locations. The mechanism behind this is not clearly understood. However, features which are thought to enhance this effect are:

- close spacing of turbines in linear rows
- tower height to rotor diameter ratio less than approximately 0.75
- stable atmospheric conditions
- topography leading to different wind directions being seen by the blades at different points in their rotation

It is difficult to quantify the degree of amplitude modulation even though it is possible to identify the effect from examination of a graphical display of variation in noise level. Evaluation of the significance of such effects is not covered by any recognised process. Because such effects may, like tonal noise, give the impression of a noise which is 5 dB or more louder than a noise of the same level without any such components, methods are being developed using complex signal processing to allow such evaluation to be repeatedly and consistently carried out such that appropriate corrections can be applied where necessary for regulatory purposes.

3.4 Subjective Response to Wind Turbine Noise

Human subjective response to noise depends on a number of factors as well as overall noise level, including the characteristics of the noise, the duration and time of exposure, the activity being carried out during exposure to the noise, the expectations which the person has of their acoustic environment, the level of noise from other sources, hearing sensitivity and non-acoustic influences, such as attitude towards the noise and general health. It is well established that people respond differently to different types of noise. Different individuals will also respond differently to the same type of noise. In general people are prepared to tolerate higher levels of road traffic noise than noise from commercial installations or premises.

Traditionally, wind turbines tend to be installed in areas of low background noise and, particularly at night, it is often the case that there may be no other significant sources of noise other than the noise of the wind as it blows through trees and other foliage. Additionally, people often chose to live in rural areas specifically because they value the lack of noise from man made sources, so any such noise which is audible may be a source of disturbance/ annoyance[12] and possibly complaint.

Although tonal noise is no longer a significant issue from turbines, excessive amplitude modulation can attract additional attention, particularly if this can be heard whilst trying to get to sleep either at the start of the night or when a person has been woken up by other causes. Although the level of noise generated internally, even with windows open, is usually insufficient to cause sleep disturbance, the stress it may generate, even if only just audible, may be sufficient to extend the time required to fall asleep. This is likely to be exacerbated by excessive audible amplitude modulation, the level of which itself may vary with time, where it draws additional attention to the noise.

Wind turbines installed on EPA licensed sites, many of which are located in mixed residential and industrial areas rather than quiet rural locations, are likely to be perceived as an addition to the plant and equipment which is already in use at such sites rather than a completely new noise source. As a result, it is possible that such installations may be accepted more readily as they will not be perceived to change the character and acoustic environment of the area as a completely new development might.

4. POTENTIAL NOISE IMPACTS OF WIND TURBINE OPERATIONS

4.1 Operational Noise Impacts

Noise is generated by wind turbines as they rotate to generate power. This only occurs above the 'cut-in' wind speed and below the 'cut-out' wind speed. Below the cut-in wind speed there is insufficient strength in the wind to generate efficiently and above the cut-out wind speed the turbine is automatically shut down to prevent any malfunctions from occurring. The cut-in speed at turbine hub height is normally between 3 and 5 metres per second (m/s) and the cut out wind speed is normally around 25 m/s.

Noise levels are greater when the wind is blowing from the turbines towards the receiver location. With cross-winds (where the wind blows across a path between the turbine and the receiver), noise levels can be expected to be around 2 dB lower than downwind noise levels. For upwind propagation, (i.e. where the wind blows from the receiver towards the turbine), the noise level can be expected to be at least 10 dB lower. Exception to this 10 dB reduction occur within a distance of up to five times the hub height or where the ground falls away rapidly between the turbine and the receiver.

Although wind turbines are often situated in rural locations where there is little other man-made noise, turbine noise can be masked by wind as it blows through trees and other foliage. This can be very helpful in reducing the impact of turbine noise, particularly for variable speed turbines at low wind speeds. The lower noise output at low wind speeds is masked by the low wind generated background noise. Caution should, however, be applied in any assumptions made about turbine noise and masking from wind effects. Due to the heights of modern commercial wind turbines and 'stable' atmospheric conditions during the night-time hours, the wind speed at ground level may be low but wind speed at hub height may be sufficient to generate significant noise levels. This is sometimes referred to as the '**wind shear'** effect. As a result of this effect, it is important to quantify background noise in terms of measured or derived **hub height** wind speed. Site specific wind shear can be calculated by analysis of wind speed data collected at different meteorological wind vane heights and applied to generate hub height derived wind speed data. It can be acceptable to convert the hub height wind speeds to standardised 10 metre height wind speeds for comparison with manufacturer's noise data without introducing any additional wind shear effects.

Modelling of Turbine Noise Impacts

At any given time turbine noise impact depends on wind speed, wind direction and background noise. The only recognised methodology for aggregating the impact as it varies with wind conditions would be to calculate a yearly L_{Aeq}, or yearly L_{den}[iii] and L_{night}[iv] values in line with the European Environmental Noise Directive 2002/49/EC[13]. There is no conclusive evidence that this correlates better with perceived impact than 'worst case' conditions[v] although there will inevitably be a mitigating factor of how often such worst case conditions occur. Noise impact is therefore usually quantified as a worst case compared to either a maximum noise limit or noise limits derived for different wind speeds.

[iii] The L_{Aeq} over 1 year with 5 dB added to noise levels during the evening (1900-2300) and 10dB added to noise levels at night (2300-0700) to allow for increased sensitivity at these times.

[iv] The L_{Aeq} over 1 year of noise measured during the night period.

[v] Usually downwind propagation under critical wind speed conditions

4.2 Noise Sensitive Locations

Noise sensitive locations (NSLs) are deemed to be any location in which the inhabitants can be disturbed by noise from the site (including turbine noise). This incorporates the previous definition for a NSL[vi] provided in the previous agency guidance notes which also covers the definition for a NSL[vii] provided in the Department of the Environment, Heritage and Local Government's (DoEHLG's) 2006 guidance document 'Wind Farm Planning Guidelines'.

[vi] Any dwelling house, hotel or hostel, health building, educational establishment, place of worship or entertainment or any other facility or other area of high amenity which for its proper enjoyment requires the absence of noise at nuisance levels

[vii] Includes any occupied dwelling house, hostel, health building or place of worship and may include areas of particular scenic quality or special recreational amenity importance

5. PLANNING LEGISLATION AND REQUIREMENTS

5.1 Irish Planning Legislation Pertaining to Wind Turbines

In general, wind turbines need planning permission unless specifically exempted. The Planning and Development Regulations 2008 (S.I. 235 of 2008) amended by the Planning and Development Regulations 2001 to 2010 provides an exemption as Class 56(c) for renewable energy technologies for commercial, public, industrial and agricultural buildings where the proposed development complies with the following:

1. The turbine shall not be erected on or attached to the premises or building or any other structure within the curtilage of the building or premises.
2. The total height of the turbine shall not exceed 20 metres.
3. The rotor diameter shall not exceed 8 metres.
4. The minimum clearance between the lower tip of the rotor and ground level shall not be less than 3 metres.
5. The supporting tower shall be a distance of not less than the total structure height (including the blade of the turbine at the highest point of its arc) plus:
    a. 5 metres from any party boundary,
    b. 5 metres from any non-electrical overhead cables,
    c. 20 metres from any 38kV electricity distribution line,
    d. 30 metres from the centreline of any electricity transmission line of 110kV or more.
6. The turbine shall not be located within 5 kilometres of the nearest airport or aerodrome, or any communication, navigation and surveillance facilities designated by the Irish Aviation Authority, save with the consent in writing of the Authority and compliance with any condition relating to the provision of aviation obstacle warning lighting.
7. Noise levels must not exceed 43db(A) during normal operation, as measured from the nearest party boundary.
8. Not more than one turbine shall be erected within the curtilage of the premises or building.
9. All turbine components shall have a matt, non-reflective finish and the blade shall be made of material that does not deflect telecommunication signals.
10. No sign, advertisement or object, not required for the functioning or safety of the turbine shall be attached to or exhibited on the wind turbine.
11. The turbine shall not be located within an Architectural Conservation Area.

Where a wind turbine does not qualify for this planning exemption, the application must be made under the Planning and Development Acts 2000 to 2010. Under Category 3(i) of the Fifth Schedule Part II of the Planning and Development Regulations 2001 (S.I. No. 600 of 2001), an environmental impact statement (EIS) is required where the energy production is generated by more than five turbines or having a total output greater than 5 megawatts.

For sub-threshold turbine developments (i.e. less than the threshold of five turbines or having a total output less than 5 megawatts), a local authority may still request an EIS if the development is considered to have potentially significant impacts. Where a development is not associated with significant impacts, an Environmental Report may be requested to accompany the planning application. This is a more limited form of an EIS and only focuses on the environmental topics where impacts are likely to occur. These topics should be agreed in advance through scoping with the relevant authorities.

For proposed wind turbine development on EPA licensed sites, the licensee must consult with the Agency at the pre-planning stage. Even in cases where a wind development proposal on an EPA licensed site is shown to be exempt from normal planning requirements, the licensee must still submit the proposed details to the Agency (including but not limited to the maximum hub height, maximum rotor diameter, maximum turbine power output and maximum sound power output. The proposed wind development must comply with licence conditions and/or assessment under this guidance note or any future guidance notes.

5.2 Planning Application Requirements

Typically noise assessments must show that the sites will not create unacceptable noise impacts. It must be prepared in accordance with the DoEHLG's document 'Wind Farm Planning Guidelines' which provides monitoring requirements and daytime/ night-time compliance limits:

- 35-40 dB(A) for quiet daytime environments of less than 30 dB(A)
- 45 dB(A) for daytime environments greater than 30 dB(A)
- 5 dB(A) above background levels when background is greater than 40 dB(A)

5.3 Example of Noise Related Conditions of Planning

The DoEHLG Wind Farm Planning guidance document requires that planning conditions for operational noise should address the issues of:

- Level limits
- Locations at which those limits apply
- Time of day at which the limit applies
- Parameters to be measured for control purposes
- Access to data generated by the monitoring programme

Section 98(I) of the EPA Act 1992 (as amended by section 256 of the 2000 Planning Act) provides that, where a Planning Authority grants planning permission for development in relation to an EPA licensed site, that the Planning Authority cannot impose conditions for the purposes of controlling emissions from the operation of the activity. The operational noise limits will be set by the Agency for any licensed site. Control of construction noise, including noise limits determined by day or time of day, is however regulated by the Planning Authority for the construction period.

Three examples of construction and operational noise conditions applied by local authorities are provided below:

EXAMPLE 1

During the construction phase, noise levels shall not exceed the background level by more than 6d B(A) at any time when measured at any external position at an occupied dwelling. Noise from the site shall be measured as L_{Aeq} (15min). The background level shall be measured in the absence of any noise from the site on days and at times when construction operations would normally be carried out on the site.

EXAMPLE 2

Noise levels, as measured externally from nearby properties, shall not exceed those limits as set out in the Wind Energy Development Guidelines for Planning Authorities, during hours of operation.

Where noise levels exceed those specified, the developer shall submit detailed proposals for ameliorating the excessive noise levels.

EXAMPLE 3

Noise levels emanating from the proposed development following commissioning when measured externally at a noise sensitive location shall not exceed the greater of 43dB(A) L_{90}, or 5dB(A) above background levels.

If the noise contains a discrete, continuous note (whine, hiss, screech, hum, etc.), or if there are distinct impulses in the noise (bangs, clicks, clatters or thumps), or if the noise is irregular enough in character to attract attention, a penalty of +5 dBA shall be applied to the measured noise level and this increased level shall be used in assessing compliance with the specified levels.

All noise measurements shall be made in accordance with I.S.O. Recommendations R1996/1, 2 and 3 "Acoustics – Description and measurement of Environmental noise".

6. NOISE GUIDANCE, STANDARDS AND LEGISLATION

6.1 Noise Legislation in Ireland

Existing noise legislation in Ireland provides for the strategic control of environmental noise from major infrastructure and industry while also providing for control of noise at specific sources and the method in which noise nuisance can be tackled.

The strategic control of environmental noise is directed by the Environmental Noise Regulations (S.I. 140 of 2006) which transposed EU Directive 2002/49/EC. This Directive was developed to provide a common framework to avoid, prevent, or reduce the harmful effects of environmental noise. The regulations focus on the process for addressing environmental noise from major infrastructure such as airports, major roads, and large agglomerations. Environmental noise from IPPC sites also falls under these regulations. These regulations provide for the generation of strategic noise maps and action plans to reduce the effects of environmental noise.

For more local scale noise, Sections 106 to 108 of the Environmental Protection Agency Act 1992 allow for control of environmental noise by the Agency (Section 106), the powers prescribed by the Act to a local authority or the Agency to prevent or limit noise (Section 107), and the provision for complaints on noise nuisance to be taken to the District Court by any person or agency (Section 108).

Section 107 relates typically to noise from sites regulated by the Agency or a local authority. This allows local authorities or the Agency to serve notices on premises/ sites where prevention or limitation of noise is required. The Environmental Protection Agency Act, 1992 (Noise) Regulations 1994 (SI No 179 of 1994) provides for a prosecution where there is a failure to comply with the requirements of the issued notice.

Section 108 of the Act allows for any person, local authority or the Agency to make a complaint to the District Court where noise levels are considered to be generating a reasonable cause for annoyance. Where the court finds in favour of a noise nuisance complaint, the person or body responsible for the noise must reduce it to a specific level, to limit it or cease it altogether.

6.2 Relevant Noise Measurement Standards

The following section details the relevant noise measurement standards for turbine and licensed sites.

ISO 1996-2:2007 Acoustics — Description, measurement and assessment of environmental noise — Part 2:Determination of environmental noise levels

This standard provides general advice on the quantification of environmental noise from various sources and includes a methodology for evaluating and correcting the measured noise level allowing for any tonal content (ISO 1996 - Part 2:2007 Annexes C and D).

ISO 9613-2:1996, Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General method of calculation

This standard provides a methodology for the prediction of noise levels in the community where the source sound power levels are known. It is often used for the prediction of wind turbine noise and validation measurements have shown it to give accurate results provided certain assumptions are used in its implementation. Specifically these relate to the attenuation from ground effects and attenuation from barriers where, if used as intended, the predictions give results which are lower than occur in practice.

IEC 61400-11, Wind Turbine Generator Systems – Part 11: Acoustic noise measurement techniques

IEC -61400-11 is the most important standard applying to wind turbine noise since it prescribes the methodology for quantification of the noise at source. It describes the microphone positions to be used, the noise and wind speed measurements to be carried out, the information to be recorded and the results to be presented.

It requires the **sound power levels** to be quantified for 'standardised'[viii] 10 metre height wind speeds from 6 m/s up to rated power although results are often published to include a greater range of wind speeds. The results of measurements carried out according to this standard, including allowances for un-certainty as appropriate, are used as the basis for manufacturers warranted sound power data.

6.3 Irish and UK Guidance

This section details applicable Irish and UK guidance. Other European guidance is provided in Appendix 1.

Guidance Applicable in Ireland

As previously referenced, The DoEHLG's 2006 guidance document *Wind Farm Planning Guidelines* is the principal guidance document covering turbine noise issues used in Ireland. It supersedes the advice contained in the Irish Planning Institute 1995 document *Planning Guidelines for Wind Energy*. In addition, a number of different planning authorities apply their own guidance in setting planning limits.

The DoEHLG document states that '*Noise impact should be assessed by reference to the nature and character of noise sensitive locations. In the case of wind energy development, a noise sensitive location includes any occupied dwelling house, hostel, health building or place of worship and may include areas of particular scenic quality or special recreational amenity importance. Noise limits should apply only to those areas frequently used for relaxation or activities for which a quiet environment is highly desirable. Noise limits should be applied to external locations, and should reflect the variation in both turbine source noise and background noise with wind speed. The descriptor[ix], which allows reliable measurements to be made without corruption from relatively loud transitory noise events from other sources, should be used for assessing both the wind energy development noise and background noise. Any existing turbines should not be considered as part of the prevailing background noise.*

[viii] Hub height wind speed converted to 10 m height based on an assumed ground roughness of 0.05m.
[ix] The L_{A90} measurement index.

In general, a lower fixed limit of 45 dB(A) [L_{90}] *or a maximum increase of 5dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours. However, in very quiet areas, the use of a margin of 5dB(A) above background noise at nearby noise sensitive properties is not necessary to offer a reasonable degree of protection and may unduly restrict wind energy developments which should be recognised as having wider national and global benefits.*

Instead, in low noise environments where background noise is less than 30 dB(A), it is recommended that the daytime level of the $L_{A90,\ 10min}$ *of the wind energy development noise be limited to an absolute level within the range of 35-40 dB(A).*

Separate noise limits should apply for day-time and for night-time. During the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. A fixed limit of 43 dB(A) will protect sleep inside properties during the night."

Guidance Applicable in the UK

Separate planning policy applies in England, Scotland, Wales and Northern Ireland. However, the relevant planning policy for each administrative area refers to the ETSU-R-97 report 'Assessment and Rating of Noise from Wind Farms' (ETSU for the Department of Trade and Industry, 1996)[14] for guidance on the assessment of wind turbine noise.

ETSU-R-97 specifies that separate noise limits should apply for day-time and for night-time like the Irish DoEHLG guidance. These limits are applicable up to a wind speed of 12 m/s at a standardised 10 m height on the site because of the combined difficulty of measuring noise at high wind speeds, the lack of turbine noise data at higher wind speeds, and the fact that it is usually lower wind speeds which are more critical for noise assessment purposes. It should be noted that for modern pitch regulated turbines, there is usually no noise increase above the speed at which rated power is reached.

For daytime periods, the noise limit is 35 to 40 dB L_{A90} or 5 dB above the 'quiet day-time hours prevailing background noise', whichever is the greater. Quiet day-time periods are defined as evenings from 18:00-23:00, Saturday afternoons from 13:00-18:00 and Sundays from 07:00-18:00. The actual value within the 35-40 dB L_{A90} range depends on the number of dwellings in the vicinity, the effect of the limit on the number of kWh generated, and the duration of the level of exposure.

For night-time periods (defined as 23:00-07:00), the noise limit is 43 dB L_{A90} or 5 dB above the 'prevailing night-time hours background noise', whichever is the greater. The 43 dB L_{A90} lower limit is based on a sleep disturbance criteria of 35 dB L_{Aeq} with an allowance of 10 dB for attenuation through an open window and 2 dB subtracted to account for the use of L_{A90} rather the L_{Aeq}.

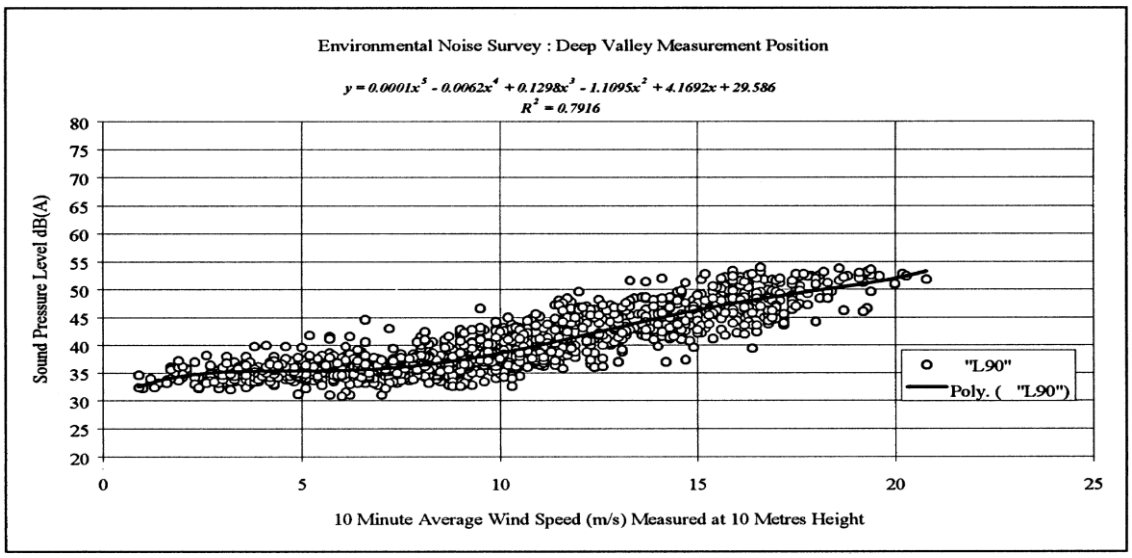
Where the occupier of a property has some financial involvement with the wind farm, the daytime and night-time lower noise limits can be increased to 45 dB L_{A90} and consideration can be given to increasing the permissible margin above background.

The prevailing background noise level is set by calculation of a best fit curve (Figure 5) through values of background noise plotted against wind speed as measured during the appropriate time period with background noise measured in terms of $L_{A90,10min}$.

Reference is made to measuring wind speed at 10 metres height for these purposes but this can lead to problems associated with the speed increase between 10 meters and hub height (the wind shear) which is dependant on atmospheric as well as ground factors and is unlikely to be constant for any given site.

Recent agreed practice in the UK[15] suggests that, for the purposes of background noise measurements, background noise measurements should be referenced to hub height wind speed although, to provide consistency with manufacturer's data, this is standardised to 10 metres height as per the requirements of IEC61400-11.

Figure 5: Example of a Best Fit Curve for Prevailing Background Noise[16]



Where predicted noise levels are low at the nearest residential properties, a simplified noise limit is suggested such that noise is restricted to an L_{A90} level of 35 dB for wind speeds up to 10 m/s at 10 m height. This removes the need for extensive background noise measurements for smaller or more remote schemes.

It is stated that the L_{A90} noise descriptor should be adopted for both background and wind farm noise levels and that, for the wind farm noise, this is likely to be between 1.5 and 2.5 dB less than the L_{Aeq} measured over the same period. Use of the L_{A90} descriptor for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

The ETSU-R-97 document also specifies that a penalty should be added to the predicted noise levels, where any tonal component is present. The level of this penalty is described and is related to the level by which any tonal components exceed audibility.

7. NOISE LIMITS

Noise limits are normally set such that the majority of the population are not disturbed by the noise levels specified. It is therefore inevitable, that some people may be annoyed by the permitted noise levels. As noise level decreases, the likelihood of disturbance decreases.

It is well established that noise which is attributable to an individual, company or other organisation causes more annoyance, in general, than noise from a source which is not attributable to any specific person or group such as road traffic. Noise from individuals, such as neighbours or other community sources, tends to cause the most annoyance.

7.1 Review of Noise limits in Existing EPA Noise Guidance

The second EPA noise guidance note (NG2) 'Guidance Note for Noise in Relation to Scheduled Activities' contains generally applicable noise limits of 55 dB $L_{Ar,T}$ for daytime (08:00-22:00) and 45 dB L_{Aeq} for night-time (22:00-08:00). Tonal and impulsive noise should be avoided during daytime hours but the daytime $L_{Aeq,T}$ can be corrected arithmetically for the presence of tonal and impulsive noise as $L_{Ar,T}$. At night there should be no tonal or impulsive components.

It is noted that in particularly quiet areas where the background noise levels are below approximately 35 dB L_{90} (likely to be L_{A90}), lower noise limits may be more appropriate.

7.2 Different Approaches in Relation to Wind Turbine Noise Limits

Noise assessment is usually based on comparison of predicted external noise levels with established criteria. Such criteria may be relative, absolute, or a combination of the two.

7.2.1 Relative criteria

Relative criteria are based on levels of existing noise and may be set either:

- according to the change in a given noise index (for instance, increase in road traffic noise is quantified in terms of a change in L_{Aeq} or L_{A10}) or
- according to a new level of sound in one index relative to the existing level of sound using a different index (for instance where the L_{Aeq} of new noise is compared to the L_{A90} of existing background noise).

7.2.2 Absolute criteria

Absolute criteria are fixed and independent of background noise but may vary according to type of area (urban, sub-urban, rural residential) and time of day (day, evening and night).

7.2.3 Hybrid criteria

The typical limits used to assess wind turbine noise are a combination of relative and absolute criteria.

The DoEHLG guidance for wind farm planning contains daytime noise limits which are a combination of relative and absolute criteria with fixed limits applying when existing levels are low, and limits set relative to existing noise levels when those existing levels are above a certain value. Night-time noise limits are absolute and do not change with background level.

The ETSU-R-97 limits used in the UK for daytime and night-time are also a combination of relative and absolute criteria, also with fixed limits applying when existing levels are low, and limits set relative to existing noise levels when those existing levels are above a certain value.

The noise limits which apply in Europe, with the exception of those applied in France, are fixed although some are set to apply at particular wind speeds and others, those which are generic rather than wind turbine specific, apply irrespective of wind speed effectively forming a cap to the allowable noise which can be generated. In France, the limits are entirely relative to the existing noise level.

Where the limits are set relative to existing noise level, baseline measurements are required in order to determine these limits. The results of baseline noise necessarily depend on what noise occurs during the periods of measurement and, to a certain extent, on the location chosen for the measurements. There may, therefore, be a limit on the precision in such measurements and they should be viewed as providing results which are representative of the conditions prevailing at the time of the measurement(s).

7.3 Proposed Wind Turbine Noise Limits for EPA Licensed Sites

The development of commercial-scale wind turbines at Agency licensed sites is a relatively new practice, and the determination of suitable noise limits can be seen to present certain challenges as a result.

This arises principally due to the differing nature of the characteristics of noise from wind turbines relative to typical noise from licensed facilities, and the equally different nature of the noise limits that govern each type of activity in Ireland.

EPA noise limits are normally set to control fixed noise level sources, and fixed noise limits are therefore appropriate. As described in Section 7.1, Agency noise limits tend to be fixed at 45 dB L_{Aeq} night-time and 55 dB $L_{Ar,T}$ daytime, although this can vary. These limits are typically applied to noise at the site boundary and at noise sensitive locations (NSLs).

As previously outlined in the Guidance Note for Noise in Relation to Scheduled Activities, 2nd Edition (EPA, 2006), in some situations it may not be appropriate to fix limits for NSLs, if, in fact, there are no NSLs in the vicinity of the activity. In such cases there is a possibility that over time, NSLs may become established near or adjacent to the activity. In these situations, it may be more appropriate to apply boundary limits for noise, thus protecting all of the lands outside the boundary, preserving it for possible future development. Boundary limits should also be set in situations where compliance monitoring is required, but where there may be problems with free access to NSLs for the taking of measurements.

Unlike typical noise sources at licensed sites, wind turbine noise is directly related to wind speed. Wind turbine noise guidelines in Ireland are set out by the DoEHLG guidance and are based on the principle that turbine noise should be controlled with reference to fixed limits when background noise is low, or relative to background noise itself as it increases with wind speed, whichever is the greater. A common interpretation of these limits is that turbine attributable noise should be limited to:

- 43 dB L_{A90} or 5 dB above background noise, whichever is the greater at NSL for night-time hours

- 45 dB L_{A90} or 5 dB above background noise , whichever is the greater at NSL for daytime hours
- 35 to 40 dB L_{A90} or 5 dB above background, whichever is the greater, at NSL for daytime hours where background noise is less than 30 dB L_{A90}

In this context, background noise is defined as a function of wind speed, over the relevant period (day or night) which is quantified by measurements prior to the site being built. It is important that such background noise measurements are referenced with wind speed at the hub height of the turbine(s) proposed, as it is this which sets the level of noise generated by the turbine.

This can be measured either directly, using conventional cup-anemometry or using LiDAR or SoDAR technologies, or derived from measurements at two lower heights (see, for instance, 'Prediction and Measurement of Wind Turbine Noise' published in UK Institute of Acoustics Bulletin Vol 34 no 2 March/April 2009).

Notwithstanding the above, all operations within licensed sites are currently required to meet the conditions of the licence. Thus, it is considered that the noise conditions should apply to the cumulative turbine and site noise. It is considered that applications can be made to the Agency in specific cases to increase the noise limits in line with the DoEHLG guidelines to allow a 7 dB exceedance of turbine noise L_{Aeq} over background noise where background noise is as defined in the preceding paragraph. This is equivalent to a 5 dB exceedance of turbine noise L_{A90} over background noise as specified in the DoEHLG guidance where 2 dB reduction is generally accepted to represent the difference between turbine noise quantified using the L_{A90} measurement index compared to the L_{Aeq} index. Turbine noise would not be permitted to contain any significant tonal components as these are not permitted at night under the standard Agency noise conditions/limits. It is now unusual for tonal components to be a significant factor in wind turbine noise.

This recommendation is in line with the general principle in continental Europe of having fixed noise limits with values similar to those which apply in Portugal, Italy and, in some circumstances, in Germany. It is also in line with the 1999 recommendations of the World Health Organisation. It is stricter than the limits which apply in Spain. It is, however, less strict than the limits which apply in Sweden and Denmark.

It is also likely to be less strict than the daytime limits which apply in cases of low background noise as per the DoEHLG guidance in Ireland, and the ETSU-R-97 guidance in the UK although the night-time limit will be very similar. It is also likely to be less strict that the guidance which currently applies in France for both daytime and night-time when background level is low.

An additional condition is included requiring that the turbine noise should not exceed 45 dB L_{Aeq} during both daytime and night-time periods. The cumulative site noise limits are therefore as follows:

Proposed Cumulative Site and Turbine Noise Limits

- Daytime 55 dB $L_{Ar,T}$
- Night-time 45 dB L_{Aeq}
- Wind turbine noise not to exceed 45 dB L_{Aeq} at any time, or to contain any significant tonal components

These limits apply up to a standardised 10 m height wind speeds of 12 m/s.

It is anticipated that the majority of applications for turbines on Agency licensed sites would be able to meet the fixed limits and that applications to increase the limits would need to be subject to particular scrutiny.

The procedure used in ETSU-R97 whereby a 'best fit' curve is fitted to a scatter plot of background noise against wind speed has been extensively criticised at a number of UK Public Inquiries. This criticism has also arisen in consultation responses to planning applications and other published material, especially where there is significant scatter in the data due to background noise sources un-related to wind effects which may vary significantly over the night-time or other measurement period. This is caused when routine background noise measurements are not always carried out with a strict attention to detail, and results may depend on the exact measurement location, time of year, effects of wind direction, effects of erroneous data and other factors.

Section 8.2 of this guidance note (NG3) 'Determination of Background Noise' therefore specifically details how background noise monitoring is to be undertaken and the number of data points required to undertake derived limit analysis.

These limits represent best practice guidance in the application of existing EPA limits and wind turbine planning, but they cannot guarantee that complaints will not be received.

7.4 Noise Mitigation

It may be necessary to use '**noise constrained'** versions of wind turbines at some sites. This noise constraining means that the turbine's maximum rotational speed, and hence its power output, is reduced to a value below that which would apply in the non-constrained version. The fact that the turbine cannot operate up to its rated power should not be seen as a negative point necessarily but the potential power output of the turbine, under such conditions, would need to be taken into account in the planning balance.

It may only be necessary to constrain the wind turbine for specific wind speeds in specific directions. This would be suitable where receivers are predominantly in one or two directions from the site and the turbine has been predicted to generate noise levels above the applicable limits at these locations.

This would allow the turbine to operate optimally in all other directions where impact had not been determined. This approach is normally implemented within the control software which governs the turbine operation and can be pre-programmed and requires no additional input from any operator.

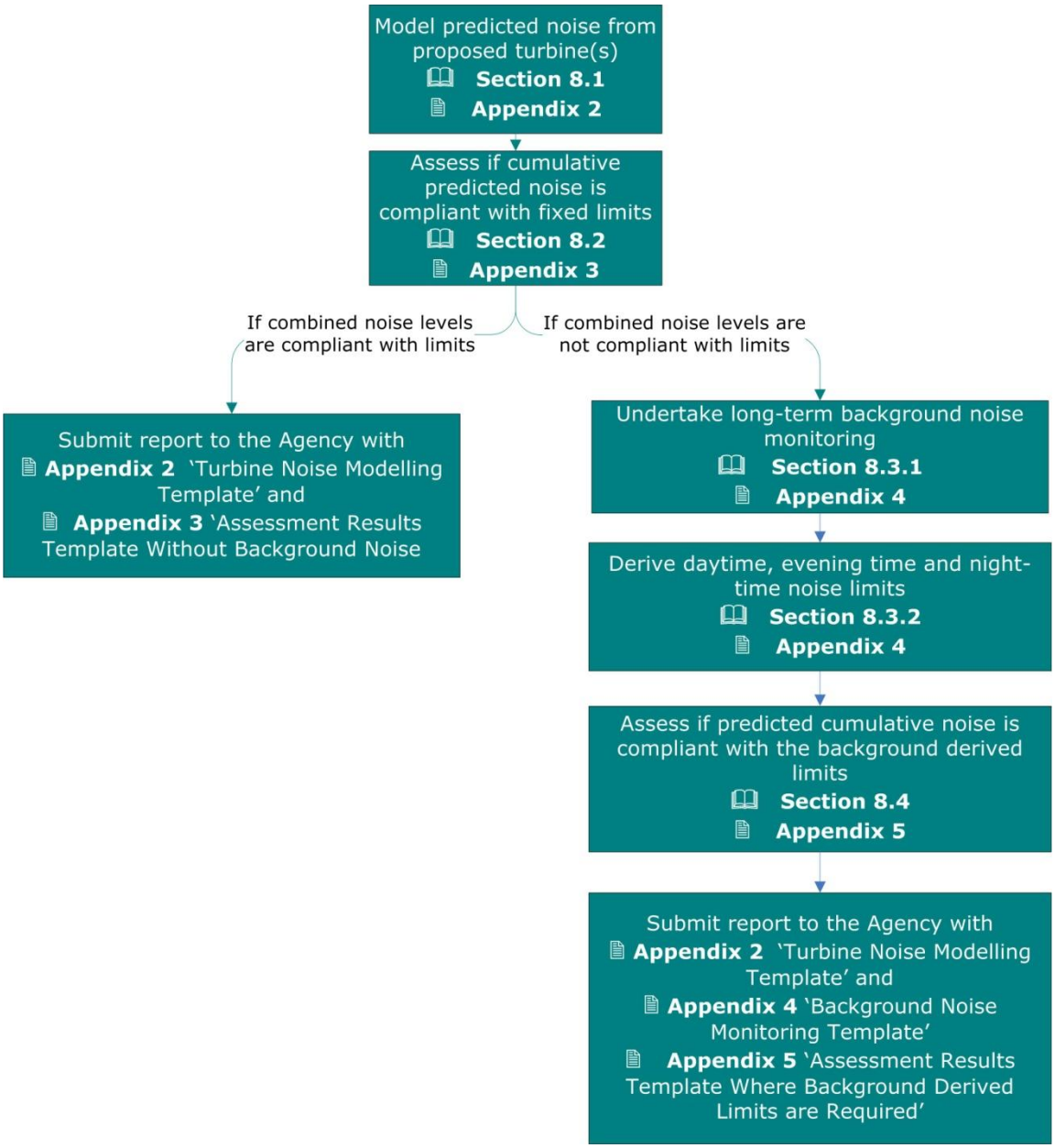
8. NOISE IMPACT ASSESSMENT METHODOLOGY

The following noise impact assessment methodology is described in order to asses predicted cumulative site noise and compliance with either fixed or background noise derived limits:

- Predicting noise levels of the proposed turbine(s) (Section 8.1)
- Assessing whether the cumulative predicted turbine and site noise is compliance with the fixed limits as per this guidance note (NG3) (Section 8.2)
- If the predicted noise levels are not compliant with the fixed limits, background noise limits can be derived (Section 8.3) and the cumulative predicted noise assessed against these (Section 8.4)

The licensee should note that compliance with the DoEHLG Windfarm Planning Guidelines (2006) and/ or operational planning conditions are not applicable for Agency licensed sites.

Figure 6: Noise Impact Assessment Flowchart



8.1 Noise Modelling of Proposed Turbines

In carrying out an assessment prior to development taking place, certain assumptions are necessary to allow predicted noise levels to represent typical conditions likely to occur in practice. These may include the source sound power levels of equipment to be installed, the ground and meteorological conditions, and the way the equipment is likely to operate in practice. Allowances are usually made to ensure that noise limits are not exceeded by likely worst case scenarios. The following procedures should be followed:

1. Turbine noise predictions should be carried out for wind speeds from cut-in (3-5 m/s) up to a standardised 10 metre height wind speed of 12 m/s. Sound power data is rarely supplied above this wind speed (see Section 6.3 for guidance applicable in the UK).
2. The predictions should be carried out using the methodology defined in ISO 9613-2, Acoustics – Attenuation of Sound during Propagation Outdoors – Part 2: General method of calculation applying the following modelling parameters:[x]
    a. The ground coefficient[xi] should be modelled as G=0.5, as recommended in 'Prediction and Measurement of Wind Turbine Noise'[17], except where transmission will be over completely hard ground or water when a value of G=0 should be used.
    b. The assumed sound power levels should be those guaranteed by the manufacturer of the proposed turbine and should be backed up by a warranty statement.
    c. The assumed receiver height should be 4 metres even if the receiver is a one storey property.
3. Predictions should be carried out using an assumed octave band noise spectrum taken from a turbine test report for each wind speed where available, or for the reference wind speed of 8 m/s, if not.
4. Attenuation for topographical or other shielding should only be applied where the whole of the turbine is out of line of site, when an attenuation of 2 dB may be assumed.

Appendix 2 'Turbine Noise Modelling Template' of this guidance note (NG3) should be completed for modelling details and results.

8.2 Assessment of Predicted Cumulative Site Noise Against Fixed Limits

Following prediction of the turbine noise, the cumulative rated site noise level should be predicted by adding together the existing rated site noise and the predicted turbine noise levels. Existing site noise should be provided by a verified model. Existing noise levels can also be provided by long-term measurements (at least two weeks) subject to prior agreement with the Agency on this approach.

Appendix 3 'Assessment Results Template Without Background Noise' of this guidance note (NG3) should be used to determine the predicted cumulative noise levels. Where site noise and predicted turbine noise can be shown to be compliant with the noise limits provided in Section 7.3, a report should be submitted to the Agency, along with completed Appendix 2 and Appendix 3.

[x] Predictions using a ground factor of G=0.5 and 1.5m receiver height may under predict noise levels likely to occur in practice

[xi] Ground attenuation is modelled in terms of a parameter G which varies from 0 for hard ground (paving, water, ice, concrete) to 1 for ground covered by grass, trees or other vegetation including farming land. A value of G=0.5 has been shown to give good correlation with measured data.

8.3 Deriving Background Related Noise Limits

If the predicted cumulative noise does not comply with the standard EPA limits, an application to increase the noise limits based on existing background noise may be made to the Agency.

8.3.1 Determination of Prevailing Background Noise

If the applicant seeks to apply for an increase above the standard noise limits (i.e. derivation of background related noise limits), background noise is taken to mean noise levels in the absence of site specific industrial noise at representative noise sensitive locations. Background noise measurements should take the form of an extended noise survey over a period of 1 week or more at one or more locations representative of locations where the standard EPA noise limits may be exceeded. Concurrent wind speed, wind direction and rainfall data should be collected on the site. There should be no contributing noise from the site to the noise measurements. Any exceptions to this requirement would need to be agreed with the Agency prior to undertaking the monitoring. Wind speed should be measured at, or derived for, the **hub height** of the proposed turbine(s). The commonly used noise indices of L_{Aeq}, L_{Amax}, L_{Amin} and L_{An} statistical parameters, including the L_{A90}, should be logged in 10 minute periods with rainfall and wind speed and direction logged for the same time periods. Any data corresponding to periods of rainfall would then be excluded from further analysis.

8.3.2 Deriving Noise Limits

As described in Section 7.3 'Proposed Noise Limits for EPA Licensed Sites', applications can be made to the Agency to increase the noise limits in line with the DoEHLG wind farm planning guidelines to allow a 7 dB exceedance of turbine noise L_{Aeq} over the prevailing background noise. This is equivalent to a 5 dB exceedance of turbine noise L_{A90} over background noise as specified in the DoEHLG guidance.

The background noise data should be analysed as follows:

1. Combine the background noise data with the meteorological data
2. Remove data corresponding to periods of rainfall
3. The existing background noise, as it varies with hub height wind speed, should be quantified separately for the daytime (08:00-22:00) and night-time (22:00-08:00) hours. Different wind directions may also be taken into account if this is likely to be significant. Hub height wind speed should be converted to standardised 10 metre height wind speed (see requirements of IEC 61400-11) before comparison with predicted noise levels.
4. Best fit curves for prevailing background noise should be prepared for daytime and night-time periods, as shown previously in Figure 5. Correlate noise data with wind data standardised to 10 metre height and calculate best fit polynomial (1st, 2nd, 3rd or 4th order) regression line through data. If there is no relation between noise and wind speed straightforward averaging of the data may be used. Append analysis to this document.
5. Derive noise limits. Noise limits should be derived at 7 dB above the prevailing background noise at each integer wind speed.
6. Reproduce analysis for each receiver location.
7. Save file as read-only to prevent tampering

Appendix 4 'Background Noise Monitoring Template' of this guidance note (NG3) should be completed at each stage of monitoring and submitted as part of the report to the Agency.

8.4 Assessment of Predicted Cumulative Noise against Background Noise Derived Limits

The cumulative noise (site noise and predicted turbine noise) should be assessed against the background noise derived limits. Appendix 5 'Assessment Results Template Where Background Derived Limits are Required' should be completed for compliance assessment by comparing the predicted noise level for each wind speed combined with modelled site noise, as against the derived noise limits.

9. MEASUREMENT AND MONITORING REQUIREMENTS

9.1 Requirements of a Competent Person

In line with the previous noise guidance notes, a **competent person** must possess a combination of technical knowledge, experience and skills, and must be able to demonstrate, as a minimum:

- good comprehension and experience of relevant acoustical standards, e.g., ISO 1996;
- a clear understanding of the licensing obligations with regard to noise including conducting monitoring in accordance with quality approved procedures;
- familiarity with acoustical monitoring equipment and with a range of noise indices including: L_{A1}, L_{A10}, L_{A90}, L_{Amax} and L_{Aeq},
- practical knowledge and experience of spectrum analysis - octave band, 1/3 octave and narrow band analysis
- an ability to analyse, interpret and explain results;
- an ability to perform necessary acoustic calculations and predictions, where appropriate; and
- an ability to recognise when more specialised expertise may be needed

For the purposes of wind turbine assessment (including turbine noise modelling), a competent person must be experienced with and able to demonstrate:

- Handling and analysing long term monitoring data
- A working knowledge of Standard ISO 9613-2, Acoustics – Attenuation of Sound during Propagation Outdoors – Part 2: General method of calculation and relevant updated technical advice
- Knowledge and competence in handling sound power data (including sound power octave band data) and the variables used by turbine manufacturers in quoting data
- Knowledge and competence in deriving tonal corrections from the results of narrow band analysis as necessary

9.2 Frequency of Measurement

Following the validation monitoring undertaken before turbine(s) installation (if required), verification noise measurements should be taken during the following 12 months from installation to display compliance with the fixed limits or derived site limits (if permitted). Appendix 6 of this document should be used to provide the verification monitoring data.

No further measurements will be required by the Agency unless noise complaints are received in relation to the site operations, or the Agency specifically requires monitoring.

9.3 Measurement Periods

Compliance monitoring for combined turbine and site noise assessment should be conducted over a minimum period of one week using a measurement interval of 10 minutes.

To ensure that sufficient data is measured, there should be a minimum of 50 ten minute measurements in a wind direction downwind from the turbine to the noise sensitive location (within 30 degrees of the downwind position) covering a range of wind speeds from the turbine cut-in speed to its rated power.

9.4 Measurement Positions

Measurements should be taken at the nearest noise sensitive location(s) to the site and wind turbine(s) to determine the 'worst-case' impacts from the site and turbine operations. For existing sites, the measurement locations may be specified under the site's licence and measurements should be taken as close as possible to the positions specified in the site's licence. If these positions are not accessible, alternate positions should be sought in agreement with the Agency.

The noise limits are 'free-field' levels, i.e. the impact of noise reflections have been minimised. To ensure 'free field' levels are measured, the monitoring should be positioned at least 3.5 m away from a reflecting surface at a 'typical' receiver height of 1.2 to 1.5 m.

Figure 7: Typical Long-Term Noise Monitoring Setup

As long term monitoring equipment is left unattended, the equipment should be set up in a secure area, such as a garden at a noise sensitive location pursuant on agreement with the householder. This should ensure that the equipment is not tampered with or disturbed in any way.

9.5 Measurement Equipment

Long-term noise surveys should be completed using a Type 1 Sound Level Meter (SLM) with an outdoor microphone kit. The outdoor microphone kit should allow for the meter to be stored in a lockable weatherproof box to prevent intentional tampering or weather affecting the meter. The microphone should be protected with a specific long-term microphone wind shield, following the guidance contained in "Noise Measurements in Windy Conditions" (ETSU W/13/00386/REP), (1996).

The SLM should have a recent traceable calibration either annual or biennial. The instrument should be field-calibrated prior to commencing the survey using the recommended calibration procedure and a calibrator of a known level. The meter should be checked on completion of the survey to record drift during the course of the monitoring period. The calibrator should have a recent traceable, annual calibration.

The sound level meter should be set to a frequency weighting of 'A' in accordance with international standard IEC 61672:2003 and various national standards relating to the measurement of sound pressure level representative of human hearing. The meter should be capable of recording L_{Aeq}, L_{Amax}, L_{Amin} and L_{An} statistical parameters.

The meter should be capable of logging the necessary parameters on a ten minute interval and have sufficient memory capacity to store the data. Another option is to connect the meter via a sim card modem which allows downloading of the data remotely. This also allows for checking on the correct operation of the meter remotely.

Sufficient power should be available to the meter, either through heavy duty batteries or a solar panel. If lead acid batteries are used, health and safety risk assessment should be undertaken where these are handled or transported.

Where there is a possibility that the combined noise contains tonal or impulsive components, audio recording should be included to enable subsequent spectral and temporal analysis to be carried out. This is required to derive the associated corrections to the measured noise levels for comparison against the day-time limit or to ensure that the night-time requirements are being met. Any analysis of tonal components should follow the provisions of ISO 1996 Part 2:2007 Annex C or D.

9.6 Meteorological Measurements

For background noise measurements, it is necessary to record wind speed on site, in 10-minute periods concurrent with the noise measurements. Measurements should either be at hub height or at two lower heights (on a meteorological mast) to allow estimation of hub height wind speed. If a dedicated meteorological mast is not available, wind sensors should be mounted in accordance with the National Oceanic and Atmospheric Administration's guidance 'Guidelines for Meteorological Station Reconnaissance And Meteorological Sensor Height Measurements'[18].

For measurements of turbine noise, meteorological data should be taken from the wind turbine nacelle anemometer(s), suitably corrected for the presence of the rotating blades, and yaw data.

Rainfall should, however, be measured at a location representative of the noise measurement location(s).

9.7 Noise from other sources

As the long-term measurements are unattended, the meter should be set up in a position that accurately reflects the noise levels from the site (and the turbine if operating and being monitored). A suitable location should be set up away from non-site, extraneous noise sources that could influence the overall noise levels. One of the biggest problems in measuring noise from wind turbines is that of noise from other wind induced sources such as trees and foliage.

It may be necessary to arrange for the turbine(s) to be shut down for certain periods to allow the contribution from other sources to be quantified and subtracted from the total measured noise to allow the turbine noise to be evaluated.

9.8 Reporting of Compliance Monitoring

The verification monitoring reporting template is provided in Appendix 6. This reporting does not include the assessment of any tonal or impulsive components which may require additional specialist input.

9.9 Appropriate curtailing of wind turbine operations when designated noise limits may be exceeded

Predicted turbine noise levels may show potential for noise limit exceedances at certain speeds or wind directions at modelled NSLs. If this occurs, the Agency can set specific conditions that the turbine operations are limited for specific wind speeds or directions. Acceptable mitigation techniques are provided in Section 7.4.

If such mitigation is required, the control software should provide for a logging system to record and archive when the turbine(s) were constrained.

Any proposed noise mitigation will normally be imposed through licence conditions.

10.GLOSSARY

Aerodynamic modulation
The variation in aerodynamic noise as the blades rotate. See amplitude modulation and blade swish.

Amplitude modulation
Variation in noise level. See aerodynamic modulation.

Background noise
The steady existing noise level present without contribution from any intermittent sources.

Blade swish
The variation in noise level at blade passing frequency. See amplitude modulation.

Broadband
Sounds which cover a wide range of frequencies do not have any tonal character.

Competent person
Individual possessing a combination of technical knowledge, experience and skills as outlined in Section 9.1 and can demonstrate both practical and theoretical competence.

Hub height
The height of the turbine measured from ground level to the centre of the rotor.

Infrasound
High level sound at frequencies below 20 Hz.

L_{Aeq}
The average level recorded over the sampling period. The closer the L_{Aeq} value is to either the L_{A10} or L_{A90} value indicates the relative impact of the intermittent sources and their contribution. The relative spread between the values determines the impact of intermittent sources such as traffic on the background.

L_{A10}
Refers to those A-rated noise levels in the top 10 percentile of the sampling interval; it is the level which is exceeded for 10% of the measurement period. It is used to determine the intermittent high noise level features of locally generated noise and usually gives an indicator of the level of traffic.

L_{A90}
Refers to those A-rated noise levels in the lower 90 percentile of the sampling interval; it is the level which is exceeded for 90% of the measurement period. It will therefore exclude the intermittent features of traffic and is used to estimate a background level.

L_{den}
An indicator that is a composite of long term L_{Aeq} values for day, evening and night (with the evening and night time L_{Aeq} values adjusted by +5 and +10 dB respectively).

L_{night} values
The L_{Aeq} as measured or calculated over all night periods during the year.

Low frequency noise
Noise which is dominated by frequency components less than approximately 200 Hz.

Noise Sensitive Location (NSL)
Any dwelling house, hotel or hostel, health building, educational establishment, place of worship or entertainment, or any other installation/facility or area of high amenity which for its proper enjoyment requires the absence of noise at nuisance levels.

Nacelle
Enclosure at the top of the tower containing the gearbox, generator, controller, yaw motor and cooling fans.

Noise constrained
Methods of restricting turbine rotational speed to constrain power output and resulting noise.

Pitch regulated
Pitch regulated turbines can pitch (turn) the rotor blades when the wind changes to ensure that the energy generation is optimised.

Prevailing background noise
The average background noise as it varies with wind speed as derived from a best fit curve through individual background noise values plotted against concurrent wind speed.

Rated power
The power specification for the wind turbine. The turbine will only produce this power output when the wind is above a certain speed.

Rated noise level (L_{Ar})
The equivalent continuous A- weighted sound pressure level during a specified time interval, T, plus specified adjustments for tonal character and impulsiveness of the sound.

Shadow flicker
Shadow flicker is caused when turbine blades cast moving shadows on windows in close proximity to turbines and at certain times of the year, the moving shadows could periodically block light to a room, causing light to appear to flicker. Section 5.12 of the Department of the Environment Heritage and Local Government Wind Farm Planning Guidelines recommends that shadow flicker at any dwellings or offices within 500 m of turbines should not exceed 30 hours per year or 30 minutes per day.

Sound power level
The logarithmic measure of sound power in comparison to a referenced sound intensity level of one picowatt (1 pW) per m^2 where

$$Lw = 10Log\frac{P}{P_0}\ \text{dB}$$

where p is the rms value of sound pressure in pascals and P_0 is 1 pW.

Stable atmospheric conditions
Stable atmospheric conditions are conditions under which mixing of layers in the atmosphere is minimised. This leads to a much greater increase in wind speed with height.

Stall regulated
Rotor blades on stall regulated turbines are bolted at a fixed angle which allows the blades to stall when the wind speed becomes too great.

Tonal
Sounds which cover a range of only a few Hz which contains a clearly audible tone i.e. distinguishable, discrete or continuous noise (whine, hiss, screech, or hum etc.) are referred to as being 'tonal'.

'Wind shear' effect
Turbine noise is specified with reference to hub height wind speed converted to 10 metres height assuming a standardised wind speed increase from 10 metres to hub height. In practice this speed up is governed by atmospheric conditions and, for a given 10 metre height wind speed, can result in significantly higher wind speeds than are predicted by this standardised increase. This can result in higher noise levels for a given 10 metre height wind speed.

Yaw
The angle of the turbine. For wind from the south-west, the turbine will turn to face this direction. This is referred to as the yaw angle.

APPENDIX 1: EUROPEAN GUIDANCE APPLICABLE TO NOISE FROM WIND TURBINES

European Noise Directive

As well as the national guidance used by individual member states, which are covered in subsequent sections of this Appendix, noise assessment in Europe should have regard to the European Noise Directive, the aim of which is to provide a unified means for addressing noise issues across Europe. This document specifically refers to the use of L_{den} and L_{night} for strategic noise mapping where L_{den} is an L_{Aeq} value over a whole year but with values measured or calculated during the evening period (1900-2300) subject to a +5 dB correction, and values measured or calculated at night (2300-0700) being subject to a +10 dB correction. L_{night} is the L_{Aeq} measured over all night periods. No guidance is provided as to what values of L_{den} or L_{night} are considered acceptable.

World Health Organisation Community Noise Guidelines, 1999

This guidance document recommends an external day-time limit of 55 dB L_{Aeq} to prevent serious annoyance during the daytime and evening, or 50 dB L_{Aeq} to prevent moderate annoyance, together with a night-time external noise limit of 45 dB L_{Aeq} to protect against sleep disturbance.

WHO Night Noise Guidelines for Europe

The World Health Organisation has recently published updated guidance on night-time noise levels designed to protect the public, based on external noise levels as averaged over a whole year [xii]. This recommends a target value of $L_{night,outside}$ of 40 dB where $L_{night,outside}$ is the external L_{Aeq} over a 1 year period [xiii]. It should be noted that this guideline limit is intended to cover noise from all sources at a specific location.

Denmark

Denmark was one of the first European countries to have specific legislation, published in 1991, covering wind turbine noise. This has now been revised and is now covered by the Danish Ministry of the Environment 2006 Order on Noise from Wind Turbines which specifies that noise should not exceed the following limits:

Wind Speed [xiv]	Noise Limit, dB(A)	
	Dwellings (Countryside)	Dwellings (Noise Sensitive Land Use)
8 m/s	44	39
6 m/s	42	37

[xii] This generally relies on noise mapping or other prediction methodology as measurements over a one year period are impractical and costly.

[xiii] The use of the subscript 'outside' is added by WHO for clarity only. It is numerically equivalent to the L_{night} value referred to in the EU Noise Directive

[xiv] At 10m height, corrected from hub height based on an assumption of 0.05m ground roughness

France

A wind turbine specific standard (NF S31-114 – *Acoustics – Measurement of Environmental Noise Before and After Wind Turbine Installation*) is currently being produced. At the present time, however, the applicable guidance is Decret 2006-1099 of 2006 which specifies that the combined effect of any new noise with the existing noise should not exceed the existing noise level by more than 5 dB during the day and 3 dB at night. Noise levels are required to be measured in octave bands.

Germany

No specific wind turbine noise guidance is available so the following generic limits apply.

Land Use	Noise Limit, dB L_{Aeq}	
	06:00-22:00	22:00-06:00
Industrial	70	70
Commercial	65	50
Mixed	60	45
Mostly Residential	55	40
Residential	50	35

Holland

Wind turbine noise is restricted to an L_{den} value of 47 dB and an L_{night} value of 41 dB.

Italy

A guidance document on wind turbine noise is currently being drafted but, until such time as this is available, the following generic limits apply:

Land Use	Noise Limit, dB L_{Aeq}	
	06:00-22:00	22:00-06:00
Hospital, School, City Park	50	40
Residential	55	45
Mixed Use (commercial/residential)	60	50
Intense Activity (railway, harbour, motorway)	65	55
Industrial	70	70

Portugal

No specific wind turbine noise guidance is available so the following generic limits apply:

Land Use	Noise Limit, dB L_{Aeq}	
	07:00-23:00	23:00-07:00
Sensitive Area (hospital and residential)	55	45
Mixed Area (cultural, recreational, commercial)	65	55

Spain

No specific wind turbine noise guidance is available so the following generic limits apply:

Land Use	Noise Limit, dB L_{Aeq}		
	07:00-19:00	19:00-23:00	23:00-07:00
Hospitals, Schools, Cultural Buildings	60	60	50
Residential Buildings	65	65	55
Commercial Buildings	70	70	60
Leisure and Sports Buildings	73	73	63
Industrial Buildings	75	75	65

Sweden

The Swedish environmental agency recommends a limit of 40 dB(A) at a wind speed of 8m/s at 10 metres height.

APPENDIX 2: TURBINE NOISE MODELLING TEMPLATE

Prediction Methodology	
Modelling Standard	ISO 9613 ☐ Other ☐ Explanation for use _____ _____ _____ _____ _____
Software Title (if specific software used)	
File Location	

Modelling Parameters	
Ground Factor (Source, Receiver and Middle Regions)	
Meteorological Correction	
Temperature (˚C)	
Relative Humidity (%)	

Model Inputs								
Turbine Type								
Source (Append data where possible)								
Sound Power Data	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Wind Speed _____ m/s standardised to 10 m height								
Wind Speed _____ m/s standardised to 10 m height								
Wind Speed _____ m/s standardised to 10 m height								

Wind Speed _____ m/s standardised to 10 m height								
Wind Speed _____ m/s standardised to 10 m height								
Wind Speed _____ m/s standardised to 10 m height								
Wind Speed _____ m/s standardised to 10 m height								

Receivers (add additional receivers where required)	**Reference**	**Grid Reference (6 digit E, 6 digit N)**	**Receiver Heights**
Screenshot			

Model set up by

Name (Block Letters) .....

Position .....

Signed .....

Reporting

Predicted Turbine Noise	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Receiver _____, dB L_{Aeq}							
Receiver _____, dB L_{Aeq}							
Receiver _____, dB L_{Aeq}							

Results confirmed by

Name (Block Letters) .....

Position .....

Signed .....

APPENDIX 3: ASSESSMENT RESULTS TEMPLATE WITHOUT BACKGROUND NOISE

Step 1 : Predicted Turbine Noise Level (Appendix 2)							
Predicted Turbine Noise	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Receiver ________, dB L_{Aeq}							
Receiver ________, dB L_{Aeq}							
Receiver ________, dB L_{Aeq}							

Step 2 : Cumulative Site Noise Level		
	Daytime Site Noise Rated Level, dB L_{Ar}	**Night-time Site Noise Level, dB L_{Aeq}**
Receiver ________		
Receiver ________		
Receiver ________		

Step 3 : Predicted Cumulative Noise Level Compliance Assessment Highlight noise levels which are not compliant with the limits shown								
Receiver ________	**Limit**	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime cumulative noise level, dB L_{Ar}	55							
Night-time cumulative noise level, dB L_{Aeq}	45							
Predicted Turbine Noise, dB L_{Aeq}	45							
Receiver ________	**Limit**	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime cumulative noise level, dB L_{Ar}	55							
Night-time cumulative noise level, dB L_{Aeq}	45							
Predicted Turbine Noise, dB L_{Aeq}	45							
Receiver ________	**Limit**	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime cumulative noise level, dB L_{Ar}	55							
Night-time cumulative noise level, dB L_{Aeq}	45							
Predicted Turbine Noise, dB L_{Aeq}	45							

Reported by

..... Name (Block Letters)

..... Position

..... Signed

APPENDIX 4: BACKGROUND NOISE MONITORING TEMPLATE

Site Details	
Site Name	
Licence Reference	
Site Address	

Set up of Equipment		
Date (dd/mm/yy)		
Time (hh:ss)		
Noise Meter Location Grid Reference (6 digit N, 6 digit E)		
Noise Meter set to record	**L_{Aeq}**	
	L_{A90}	
	L_{Amax}	
	L_{Amin}	
	At 10 minute intervals	
	set to nearest 10 minute period	
Noise meter calibration date (dd/mm/yy)		
Noise meter calibrator calibration date (dd/mm/yy)		
Noise meter calibrated before		
Met Loggers set to record	**Wind speed (m/s)**	
	Wind direction (degrees)	
	Rainfall (mm)	
	At 10 minute intervals	
	set to nearest 10 minute period	
Met logger calibration date (dd/mm/yy)		

Set up by

..... Name (Block Letters)

..... Position

..... Signed

Collection of Monitoring Equipment	
Note any issues on collection of noise equipment (such as power off, movement of microphone, evidence of tampering)	

Collected by
.... Name (Block Letters)
.... Position
.... Signed

Data Analysis

1. Combine noise data with meteorological data
2. Remove data corresponding to periods of rainfall
3. Segregate data into daytime 08:00 to 22:00 and night-time 22:00 to 08:00
4. Correlate noise data with wind data standardised to 10 metre height and calculate best fit polynomial (1^{st}, 2^{nd}, 3rd or 4^{th} order) regression line through data. If there is no relation between noise and wind speed, , it may be appropriate to use a simple average of all background noise data acquired over the relevant time periods as the basis for the noise limits. Append analysis to this document.
5. Derive noise limits.
6. Reproduce analysis for each receiver location.
7. Save file as read-only to prevent tampering

Reporting

Receiver ________	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Derived Daytime Limit, dB L_{Aeq}							
Derived Night-time limit, dB L_{Aeq}							
Receiver ________	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Derived Daytime Limit, dB L_{Aeq}							
Derived Night-time limit, dB L_{Aeq}							
Receiver ________	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Derived Daytime Limit, dB L_{Aeq}							
Derived Night-time limit, dB L_{Aeq}							

Reported by
.... Name (Block Letters)
.... Position
.... Signed

APPENDIX 5: ASSESSMENT RESULTS TEMPLATE WHERE BACKGROUND DERIVED LIMITS ARE REQUIRED

Step 1 : Predicted Turbine Noise Level (Appendix 2)							
Predicted Turbine Noise	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Receiver ________, dB L_{Aeq}							
Receiver ________, dB L_{Aeq}							
Receiver ________, dB L_{Aeq}							

Step 2 : Cumulative Site Noise Level		
	Daytime Site Noise Rated Level, dB L_{Ar}	**Night-time Site Noise Level, dB L_{Aeq}**
Receiver ________		
Receiver ________		
Receiver ________		

Step 3 : Derived Limits (Appendix 4)							
Receiver ________	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Derived Daytime Limit, dB L_{Ar}							
Derived Night-time limit, dB L_{Aeq}							
Receiver ________	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Derived Daytime Limit, dB L_{Ar}							
Derived Night-time limit, dB L_{Aeq}							
Receiver ________	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Derived Daytime Limit, dB L_{Ar}							
Derived Night-time limit, dB L_{Aeq}							

Step 4 : Predicted Cumulative Noise Level Compliance Assessment Highlight noise levels which are not compliant with the limits shown in Step 3							
Receiver ________	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime cumulative noise level, dB L_{Ar}							
Night-time cumulative noise level, dB L_{Aeq}							

Receiver _____	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime cumulative noise level, dB L_{Ar}							
Night-time cumulative noise level, dB L_{Aeq}							
Receiver _____	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime cumulative noise level, dB L_{Ar}							
Night-time cumulative noise level, dB L_{Aeq}							

Reported by ---------- Name (Block Letters)

---------- Position

---------- Signed

APPENDIX 6: VERIFICATION MONITORING REPORTING TEMPLATE

Site Details	
Site Name	
Licence Reference	
Site Address	

Set up of Equipment		
Date (dd/mm/yy)		
Time (hh:ss)		
Noise Meter Location Grid Reference (6 digit N, 6 digit E)		
Noise Meter set to record	**L_{Aeq}**	
	L_{A90}	
	L_{Amax}	
	L_{Amin}	
	At 10 minute intervals	
	set to nearest 10 minute period	
Noise meter calibration date (dd/mm/yy)		
Noise meter calibrator calibration date (dd/mm/yy)		
Noise meter calibrated before		
Met Loggers set to record	**Wind speed (m/s)**	
	Wind direction (degrees)	
	Rainfall (mm)	
	At 10 minute intervals	
	set to nearest 10 minute period	
Met logger calibration date (dd/mm/yy)		

Set up by ..... Name (Block Letters)

..... Position

..... Signed

Collection of Monitoring Equipment	
Note any issues on collection of noise equipment (such as power off, movement of microphone, evidence of tampering)	

Collected by

..... Name (Block Letters)

..... Position

..... Signed

Data Analysis

1. Combine noise data with meteorological data
2. Exclude data corresponding to periods of rainfall and data for non-downwind directions (downwind is defined here as wind directions from all turbines to the receiver location ±30 degrees).
3. Segregate data into daytime 08:00 to 22:00 and night-time 22:00 to 08:00.
4. Correlate noise data with wind data standardised to 10 metre height and calculate best fit polynomial (1st, 2nd, 3rd or 4th order) regression line through data. Append analysis to this document.
5. Plot applicable noise limits (either fixed or background noise derived) and correlated measurements to assess compliance with daytime and night-time limits. Refer back to Section 9.7 where it is possible that extraneous noise from other sources may have affected the measured noise levels. Append analysis to this document.
6. Reproduce analysis for each receiver location.
7. Save file as read-only to prevent tampering

Noise Limits Compliance							
Receiver _____	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime Limit, dB L_{Ar}							
Daytime cumulative noise level, dB L_{Ar}							
Night-time limit, dB L_{Aeq}							
Night-time cumulative noise level, dB L_{Aeq}							
Receiver _____	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**	**11 m/s**	**12 m/s**
Daytime Limit, dB L_{Ar}							
Daytime cumulative noise level, dB L_{Ar}							
Night-time limit, dB L_{Aeq}							
Night-time cumulative noise level, dB L_{Aeq}							

Receiver _____	6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	11 m/s	12 m/s
Daytime Limit, dB L_{Ar}							
Daytime cumulative noise level, dB L_{Ar}							
Night-time limit, dB L_{Aeq}							
Night-time cumulative noise level, dB L_{Aeq}							

Reported by

..... Name (Block Letters)

..... Position

..... Signed

APPENDIX 7: FREQUENTLY ASKED QUESTIONS

As part of the Consultation process, please submit any questions that you would like to have a brief answer included here. This section will be limited to 2 pages, so keep any queries brief.

Clarity is required on what are the "specific cases" where an increase in noise limits is permissible.

Specific cases where an increase in noise limits is permissible are not defined in this document. An application to increase the limits can be made for any case where such an increase is required or desired.

Where will the limits apply regard to locations (site boundary or residential properties)?

The DoEHLG planning guideline for wind energy development (2006) references noise sensitive locations whereas EPA licences may apply at site boundaries or residential properties or a combination of both. In some situations it may not be appropriate to fix limits for NSLs if, in fact, there are no NSLs in the vicinity of the activity. In such cases there is a possibility that over time, NSLs may become established near or adjacent to the activity. In some such cases it may be more appropriate to apply boundary limits for noise, thus protecting all of the lands outside the boundary, preserving it for possible future development. Boundary limits should also be set in situations where compliance monitoring is required, but where there may be problems with free access to NSLs for the taking of measurements.

All IPPC sites have a database of measured site noise; can this database be used as an existing baseline for assessing wind turbine noise?

The historical noise measurements taken at licensed sites include site noise. The background noise needed to assess the impact of wind turbine noise and derive background noise based limits must be taken in the absence of site noise. In addition, existing noise measurements for EPA licensed sites are taken in accordance with ISO 1996 Acoustics -- Description, measurement and assessment of environmental noise which require noise measurements to be taken at wind speeds of less than 5 m/s. These measurements would not be useful as background noise levels for wind turbine assessments would need to be taken wind speeds greater than this.

What scale of turbines does this guidance document cover?

This guidance document applies to all turbines which licensees seek to develop on EPA licensed sites. Even turbines which are exempt from the Planning and Development Regulations 2001 to 2010 must be notified to the Agency for permission to construct and operate on licensed sites.

REFERENCES

[1] Office of Environmental Enforcement (OEE) Enforcement Policy, Environmental Protection Agency

[2] Environmental Protection Agency, (2003), Environmental Noise Survey Guidance Document

[3] Environmental Protection Agency (2006), Guidance Note for Noise in Relation to Scheduled Activities

[4] EU Directive on Promotion of the Use of Energy from Renewable Sources - http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

[5] Directive of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources, 2008/0016 (COD), Council of the European Union, Brussels, December 2008;
http://www.ewea.org/fileadmin/ewea_documents/documents/00_POLICY_document/RES-directive_consolidated.pdf

[6] Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources in the internal electricity market (27 September 2001)
http://www.ewea.org/fileadmin/ewea_documents/documents/policy/external_documents/l_2832 0011027en00330040_1_.pdf

[7] Sustainable Energy Authority of Ireland, Renewable Energy in Ireland, 2010 update, http://www.seai.ie/Publications/Statistics_Publications/SEI_Renewable_Energy_2010_Update/RE_in_Ire_2010update.pdf

[8] Irish Wind Energy Association, May 2010, http://www.iwea.com/index.cfm/page/bycounty

[9] http://www.eirgrid.com/media/Contracted%20Wind%202June10.pdf

[10]http://www.seai.ie/News_Events/Previous_SEAI_events/Regional_Wind_Energy_Workshop_2010/Developing_21st_Century_Electricity_Networks_ESB.pdf

[11]http://www.seai.ie/News_Events/Previous_SEAI_events/Regional_Wind_Energy_Workshop_2010/Developing_21st_Century_Electricity_Networks_ESB.pdf

[12] Waugh, D., Durucan, S., Korre, A., Hetherington, O. and O'Reilly, B., Environmental Quality Objectives Noise in Quiet Areas, Prepared for the Environmental Protection Agency, 2003

[13] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise

[14] ETSU for the Department of Trade and Industry, (2005), Report ETSU-R-97, The Assessment and Rating of Noise from Wind Farms

[15] Bowdler, D., Bullmore, A., Davis,, B., Hayes, M., Jiggins, M., Leventhall, G. and McKenzie, A., (2009), Prediction and Assessment of Wind Turbine Noise, Agreement about relevant factors for noise assessment from wind energy project, Acoustics Bulletin, March/ April 2009, Institute of Acoustics

[16] ETSU for the Department of Trade and Industry, (2005), Report ETSU-R-97, The Assessment and Rating of Noise from Wind Farms

[17] Bowdler, D., Bullmore, A., Davis, B., Hayes, M., Jiggins, M., Leventhall, G. and McKenzie, A., (2009), Prediction and Assessment of Wind Turbine Noise, Agreement about relevant factors for noise assessment from wind energy project, Institute of Acoustics Bulletin, Vol 34 no 2 March/ April 2009

[18] Centre for Operational Oceanographic Products and Services,(April 2008), 'Guidelines for Meteorological Station Reconnaissance And Meteorological Sensor Height Measurements', National Oceanic and Atmospheric Administration