Our Reference BAK/ADS/RB/080464/13-5/L005
Your Reference Application No. 09/00141/DEEM

17 March 2010

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DEVELOPMENT SERVICES
17 MAR 2010
RECEIVED

Dear Cathy

PLANNING PERMISSION REF NO. 09/00141/DEEM
APPLICATION FOR A NON-MATERIAL AMENDMENT FOLLOWING A GRANT OF PLANNING PERMISSION.
APPLICATION TO ERRECT A ROOF MOUNTED WIND TURBINE (QR5 VERTICAL AXIS WIND TURBINE – VAWT)

Following receipt of the Planning Permission Notice and Conditions dated 16 September 2009 for the above planning permission, on behalf of our client please find enclosed an application for the non-material amendment to the original planning permission, as stated in condition 24.

The application consists of 4 No. copies of the following information:

- **Application fee** – cheque in sum of £170.00
- **Design and Access Statement**
- **Drawings**
  080464/A/ PL 07 – Roof Plan
  080464/A/ PL 11 – Site Sections
  080464/A/ PL 13 – Coloured Site Plan
  080464/A/ PL 15 – Coloured Elevations sheet 1
  080464/A/ PL 16 – Coloured Elevations sheet 2
  080464/A/ PL 17 – Coloured Perspective Views sheet 1
  080464/A/ PL 18 – Coloured Perspective Views sheet 2

We trust the enclosed information is satisfactory, but if you have any queries or require further information, please do not hesitate to contact us.

Yours sincerely



A D Smith
for Pick Everard

Encs

cc A Crowter, NWHC (letter and forms only)
T Sampson, Mace (letter and forms only)
P Homer, ISG (Letter and forms only)

DESIGN & ACCESS STATEMENT

DEVELOPMENT SERVICES
17 MAR 2010
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Proposed Roof Mounted Wind Turbine

For North Warwickshire and Hinckley College

16 March 2010

Architects
Consulting Engineers
Project Managers
Surveyors

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Checked by: SM **Date:** 16 March 2010

1.0 INTRODUCTION

The new North Warwickshire and Hinckley College (NWHC) has been designed to incorporate a number of environmentally friendly equipment and use of sustainable materials where possible to promote the colleges environmental values. These include the use of a Bio-mass boiler, rainwater harvesting and the wind turbine

This statement has been prepared in support of the Planning Application for a non-material amendment following the granting of planning permission (**Ref 09/00141/DEEM granted on 16th Sept 2009).**

This statement is to be read in conjunction with the Planning Application drawings.

2.0 SITE USE

The new Art and Drama HWHC college building shares the existing old Atkins factory site with the grade 2 listed Goddard building which has been renovated and converted into Offices as part of a joint project with Hinckley and Bosworth Borough Council (HBBC)

The site consists of:

- New three storey Multi-Media, drama and art college for NWHC
- Converted Goddard building into Offices
- Surface car parking (55 spaces including 5no Disabled spaces and cycle storage for up to 40 cycles)

The proposed site for the wind turbine is situated on top of the NWHC college building adjacent to the south elevation facing the surface Car Park.

3.0 DESIGN

The proposed qr5 quiet revolution wind turbine has been specifically conceived for use in urban settings or areas with variable wind strengths and directions
The turbine design has some key features

- Power production in an urban environment
- CO2 emission reduction
- Quiet in operation
- Aesthetically pleasing- sculptural to the eye, recognised by the RAE and D&AD Awards
- Simple to install and low maintenance
- To revolutionise power generation in the urban environment
- Generating electrical power at the point of use

NWHC are intending to install the wind turbine to supplement the power being used by the NWHC building and to reduce CO2 emissions and demonstrate that there are tangible means of reducing the carbon footprint.
The location of the turbine on the roof will be a statement to the local community of NWHC commitment to the environment

4.0 LAYOUT PROPOSALS / ACCESS

- The proposed wind turbine is to be located on the upper roof area which will only be accessed for maintenance purposes.
- Access for maintenance is annual
- The mast is designed to tilt down to allow ground level maintenance and inspection. Maintenance and inspections are carried out by suitably qualified / skilled operatives
- There will be no disruption to pedestrians or traffic during maintenance – no crane or plant is required

5.0 VISUAL APPEARANCE

The design of the quiet revolution turbine was driven by aerodynamic efficiencies, the qr5 turbine extracts 74% of the potential (betz limit) extractable power from the wind. The design of the qr5 wind turbine has been described by the National Research Centre, Canada institute for Aerospace research as impressive and was short listed for the Royal Acadamy of Engineering MacRoberts Award 2007 and won two yellow pencil D&AD Awards

6.0 SCALE

The qr5 consists of a standard 5m vertical helical turbine supported on a 3400mm mast with a turbine diameter of 3100mm. The overall scale of the unit is in keeping with the massing of the NWHC college building in our opinion

7.0 NOISE

The qr5 wind turbine is very quiet and is ideal for use in noise sensitive areas with very little impact at distances less than 35m from the turbine. Noise testing at various sites indicates that the turbine noise rises with the increase in wind speed as does the background noise level. The background levels typically rise in tandem or even faster than turbine noise levels
See appendices **'B' and 'C' ('Noise Statement' and 'The relationship between background noise levels and acoustic impact of the qr5 wind turbine'** respectively)

8.0 FIT FOR PURPOSE

The qr5 wind turbine can receive wind from any direction, there is no 'down time' as the rotor does not have to yaw to face the wind, in addition, there are no gyroscopic effects preventing yaw.
Loads are more evenly distributed with a VAWT than a HAWT which results in lower vibration making the VAWT a better option for roof mounting

9.0 EFFECTS ON WILDLIFE & NATURE CONSERVATION

Birds

When spinning the rotor appears like a semi-solid object (see separate image) and when at test sites they have been witnessed flying towards the turbine and then alter course and simply fly around the turbine

Quiet revolution turbines have a safety system to detect impacts on the rotor, but to date have had no impacts from birds on any turbines despite approx 180,000 hours of turbine operation

Following a bird study qr5 have a precedent of planning permissions being granted for their qr5 turbines after a bird impact study by ARUP concluded that the

" helical design is thought to be less potentially dangerous to birds than a fast moving rotor blade mechanism, with a significantly reduced surface area."

Bats

Bats can fly at speed through dense woodland in high winds where trees and branches are moving unpredictably and avoid collision. They can also catch small insects while flying. There is no question that bats can 'see' using their sonar, the qr5 while in operation

Quiet revolution are in dialogue with the Bat Conservation Trust to establish potential for future testing but to date no incidents have been reported despite the 180,000 accumulated hours of operation (as of November 2008)

10.0 SHADOW FLICKER

In some instances the sun may pass behind the rotor and cast a shadow onto an observer. If there is no wind the rotor will not be turning, at other times the sun will be behind clouds and there will be no shadow.

Typically in the UK on 30% of the time of the day is there both wind and sunshine. In addition, for shadow flicker to occur

- The sun must be in a position in the sky where the turbine is directly in between the sun and the viewer
- The suns position varies from day to day and hour to hour depending on the time of year
- There must be no blinds or curtains on the affected window (not applicable at NWHC College) , whereas logically it could be assumed that if direct sunlight is a common accurance that blinds would be fitted to affected windows.

For addition information see **appendix 'D' (quiet revolution shadow flicker comment)**

APPENDIX A

Qr5 Vertical Axis Wind Turbine – How it works

quietrevolution

qr5 VERTICAL AXIS WIND TURBINE

HOW IT WORKS

A wind turbine is used to convert the **kinetic energy** from the wind into **mechanical energy** which is then ultimately converted into usable **electrical energy**.

The qr5 rotor has three blades that are twisted aerofoils mounted on a vertical framework. The oncoming wind blowing through the aerofoils creates zones of pressure that generate a net force in the direction of rotation. This force causes the blades to move forward though the air in a circular path giving rise to a positive torque (rotational force) in the central shaft.

The mechanical energy arising from the torque and rotational speed is extracted and converted into electrical energy with the use of a generator. The generator is housed at the base of the rotor, it consists of a rotating set of permanent magnets surrounded by a stationary set of coil wound conductors. As the magnetic field passes the coils it generates electrical energy from a principle known as electromagnetic induction. This principle is the reverse of an electric motor which converts electrical energy into mechanical energy. The coils within the generator are grouped into sets of three and produce three separate phases of electrical energy that vary with rotor speed, therefore generating a variable three phase alternating current (AC) power supply.

The variable nature of this electrical energy needs to be stabilised into something usable. This is achieved using power electronics located on the turbine control panel, which convert the variable three phase current into a more manageable direct current (DC). This is then converted back into a three phase AC with a constant voltage and frequency suitable for grid connection and on site use.

The output from the qr5 turbine will supply local usage therefore offsetting requirements from the grid. If the output of the turbine is greater than the local usage the surplus is exported to the grid.

KINETIC ENERGY FROM WIND

↓

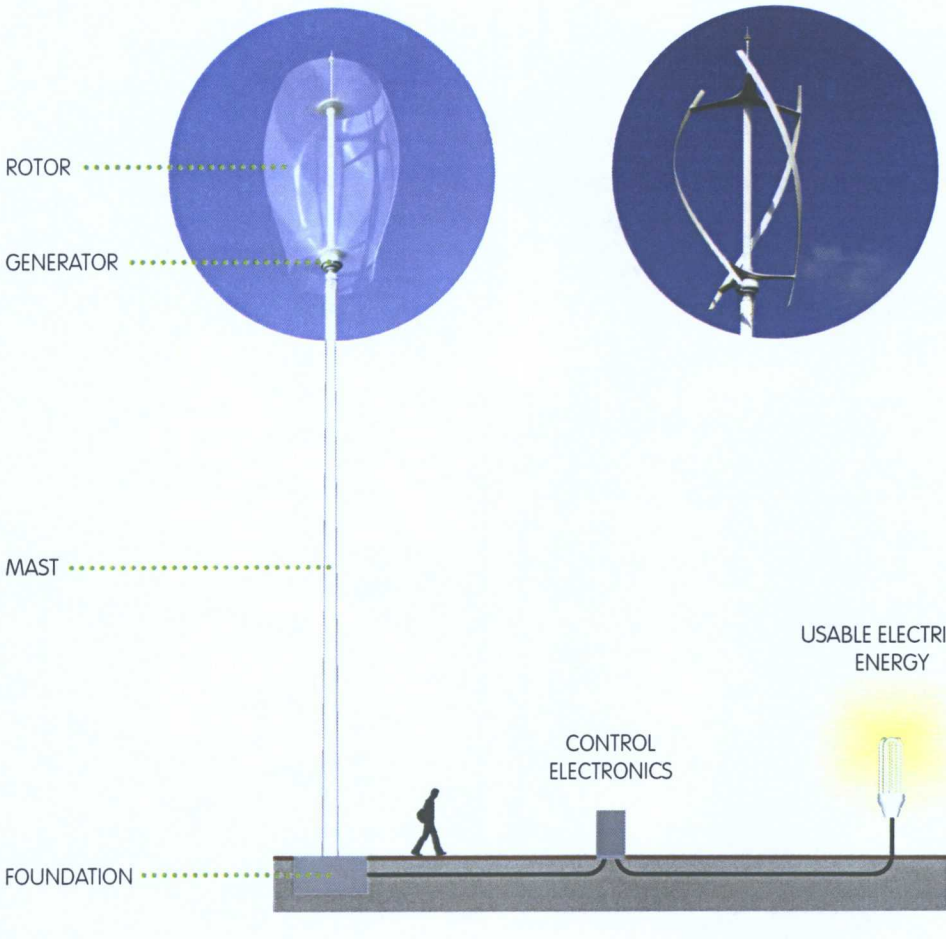
MECHANICAL ENERGY IN SPINNING ROTOR

↓

ELECTRICAL ENERGY FROM GENERATOR

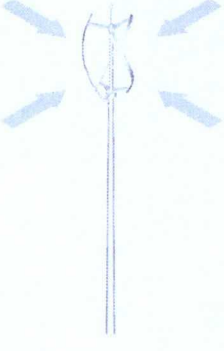
↓

USABLE ELECTRICAL ENERGY ON-SITE





Unlike traditional HAWTs the quiet**revolution** VAWT uses wind from all directions without the requirement to track the wind, therefore maximising efficiency



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ISO 9001 REGISTERED FIRM

APPENDIX B

Qr5 Noise Statement

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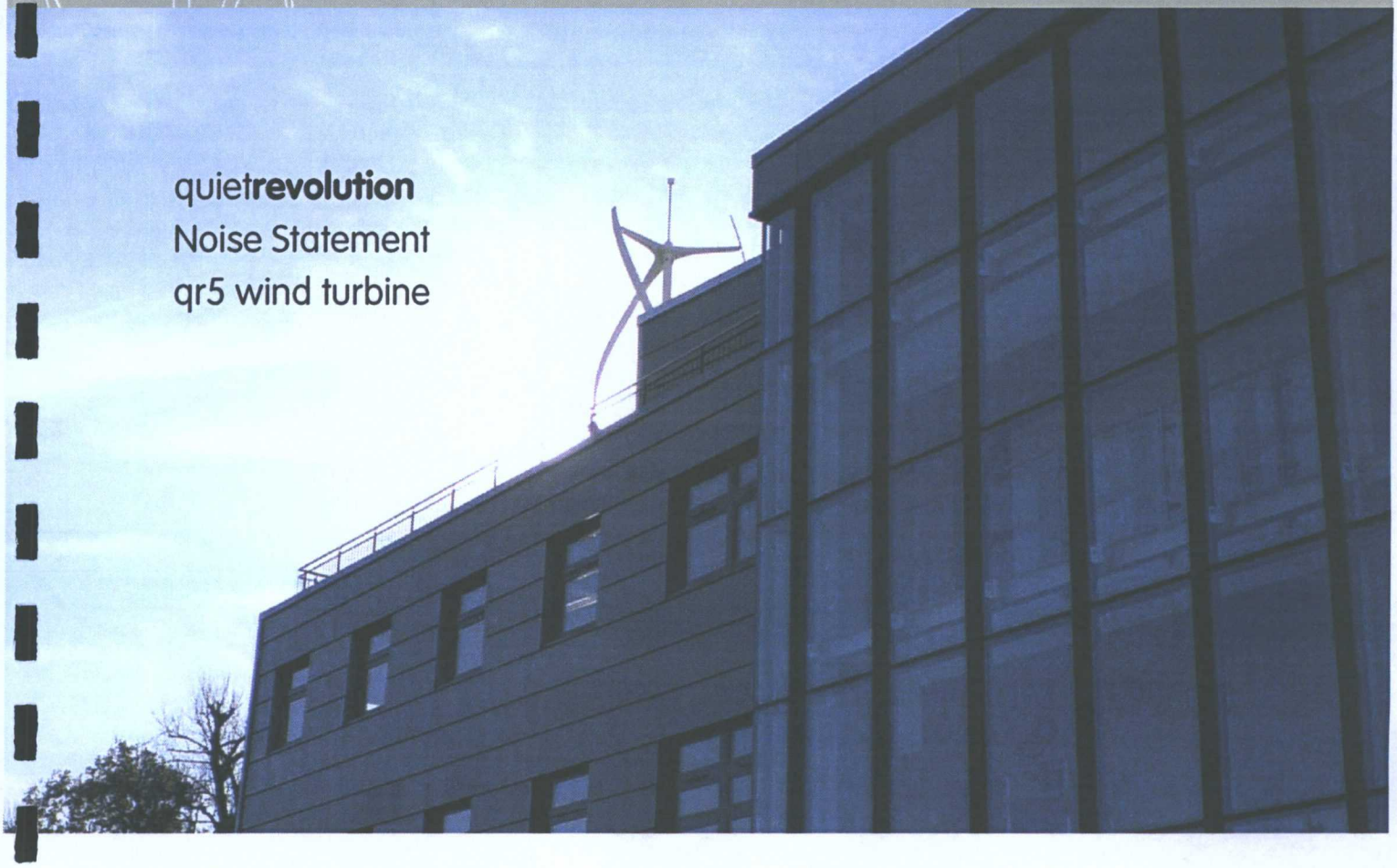

quietrevolution
Noise Statement
qr5 wind turbine

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LAST UPDATED: 18th September 2008

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1. Introduction to noise assessments for wind turbines

Noise impact has been a cause of common concern for wind turbines in the rural environment notwithstanding the fact that there are clear guidelines on how far large scale horizontal axis wind turbines ("**HAWTS**") should be positioned from residential properties to avoid causing any nuisance.

In contrast to this position the 'quiet**revolution** qr5' is a small scale vertical axis wind turbine ("**VAWT**") designed specifically for use in the urban environment where there are presently no agreed standard guidelines for measuring noise impact. Until such new standards are published (expected in the second half of 2008) this report has used a 'basket methodology' of the various current standards and guidelines to assess the noise performance of the qr5 turbine.

Existing standards and guidelines for assessing the noise impact of installing wind turbines close to 'sensitive' sites include:

- World Health Organisation ("**WHO**") Guidelines for Community Noise.
- BS 4142: 1997: Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas.
- BS 8233: 1999: Sound Insulation and Noise Reduction for Buildings - Code of Practice.
- Planning Advice Note: PAN 56: Planning and Noise (April 1999).
- ETSU-R-97: the Assessment and Rating of Noise from Wind Farms.

Out of these the most commonly used standard is *BS 4142:1997* which has one key limitation in that it recommends noise measurements be undertaken in windspeeds of 0-5 m/s when the majority of small scale turbines would in fact not be operational.

The international standard for measuring the actual noise level of an individual turbine is *BS EN 61400-11: 2003: wind turbine generator systems: acoustic noise measurement techniques.* This is the standard which quiet**revolution** has used as a basis for its noise survey.

In addition, the methods outlined in this standard can also be used for measuring the environmental noise impact at higher windspeeds than those specified in *BS 4142:1997* when the turbine would actually be operational.

It should also be noted that:

- The qr5 should only be considered a source of noise when the turbine is actually operational, i.e. when wind speeds are between 5 m/s and 16 m/s. Depending on the site there will be periods when the turbine is stationary, especially during the warmer summer months.
- Within the turbine operation range (windspeeds between 5m/s and 16m/s) the background noise level will also rise as turbine noise rises. On many sites background noise levels will often be higher than the turbine noise level.
- As manufacturers, quiet**revolution** provide rigorously measured data to provide the noise level of qr5 wind turbines in different weather conditions.
- Local planning departments or environmental health officers are concerned with the increase in noise above background levels as a result of a wind turbine being installed.

2. Summary of applicable and relevant standards

World Health Organisation ("WHO") Guidelines for Community Noise[1]

"In dwellings, the critical effects of noise are on sleep.... To avoid sleep disturbance, indoor guideline values for bedrooms are 30dB $L_{A\,eq}$ for continuous noise and 45 dB $L_{A\,max}$ for single sound events."

"...during the daytime, the sound pressure level on balconies, terraces and outdoor living areas should not exceed 50dB $L_{A\,eq}$ for a steady, continuous noise."

"...if the noise is not continuous, $L_{A\,max}$ or SEL are used to indicate the probability of noise-induced awakenings. Effects have been observed at individual $L_{A\,max}$ exposures of 45 dB or less. Consequently, it is important to limit the number of noise events with a $L_{A\,max}$ exceeding 45 dB."

"At night, sound pressure levels at the outside façades of the living spaces should not exceed 45 dB $L_{A\,eq}$ and 60 dB $L_{A\,max}$, so that people may sleep with bedroom windows open. These values have been obtained by assuming that the noise reduction from outside to inside with the window partly open is 15 dB."

"3.4 Sleep Disturbance... it is estimated that 80-90% of reported cases of sleep disturbance in noisy environments are for reasons other than noise originating outdoors."

The World Health Organisation's advice is that a 15 dB reduction across an open window (or other threshold) is a realistic assumption.

BS 4142: 1997 - Method for rating industrial noise affecting mixed residential and industrial areas[2]

This standard is used to support planning applications for the introduction of industrial type noise sources into mixed residential areas. The assessment compares the noise source with existing background noise.

Currently this is the method most often used by planning departments when assessing wind turbines. However, this standard has certain limitations that should be noted.

- The principle limitation is that BS 4142 states that noise measurements are to be undertaken at low wind speeds (0 m/s to 5 m/s).
- Many wind turbines only start operating at a wind speed of 4m/s or higher. This is because there is very little energy in the wind at low wind speeds.
- The operating range for the qr5 wind turbine is 5m/s to 16m/s. Therefore the wind speed measured under BS 4142 is not representative of the background noise levels whilst the wind turbine is in operation.

BS 4142 is usually a comparison between the acoustic characteristics of the plant in question and a background noise survey. The noise survey is required to be performed during the proposed operating hours of the plant. Noise measurements are taken during the quietest hour in the daytime and the quietest 5 minutes at night.

Following analysis and corrections to the data in accordance with *BS 4142* the difference between the source and existing noise level is determined.

BS 4142 advises that a difference of +10 dB is likely to lead to complaints. A difference of +5 dB is said to be of marginal significance.

FURTHER INFORMATION ON BS 4142

Clause 7.1.3 states:

"Make measurements during periods when the background noise level is typical of the background noise when the specific noise source is or will be operating, but is not actually operating at the time of measurement."

This clause implies that noise surveys for wind turbines should be undertaken during higher wind speeds than is usually the case under *BS 4142*. The main problem however is that wind noise will affect the microphones. However *BS EN 61400-11: 2003* has methods for measuring accurate noise levels at higher wind speeds.

quiet**revolution** advocate that a combined approach to undertaking noise measurements is undertaken by acoustic engineers.

The scope of BS 4142 specifically precludes situations where background noise levels are below 30dB(A).

BS 8233: 1999 – Sound Insulation and Noise Reduction for Buildings[3]

This standard provides values for background ambient noise levels and intermittent higher short term noise levels.

The following are indoor background ambient noise levels in spaces when they are unoccupied (L_{Aeq}).

Reasonable conditions for study and work requiring concentration:

Library, cellular office, museum		**Staff room**	
- Good:	40 dB	- Good:	35 dB
- Reasonable:	50 dB	- Reasonable:	45 dB
Meeting room, executive office		**Living room**	
- Good:	35 dB	- Good:	30 dB
- Reasonable:	40 dB	- Reasonable:	40 dB
Bedroom			
- Good:	30 dB		
- Reasonable:	35 dB		

"...these noise levels relate to steady intrusive noise only, such as plant or steady road traffic noise; they cannot be taken to apply to music noise or intermittent events."

"For a reasonable standard in bedrooms at night, individual noise events (measured with F time-weighting) should not normally exceed 45 dB L_{Amax}."

BS 8233: 1999 post-dates the initial publication of the current WHO guideline values and *BS 4241:1997,* setting 'reasonable' noise levels approximately 5 dB(A) higher than previous standards.

PAN 56 – Planning Advice Note 56: Planning and Noise – April 1999[4] (published by The Scottish Office)

"Internal levels less than 35 dB(A) L_{Aeq} are recommended to preserve the restorative process of sleep."

"Internal noise levels within individual living apartments should be less than 45 dB(A) L_{Aeq} during the day and 35 dB(A) L_{Aeq} during the night."

ETSU-R-97 - The Assessment and Rating of Noise from Wind Farms[5]

"There are two sources of noise from wind turbines; the mechanical noise from the turbines and the aerodynamic noise from the blades. Mechanical noise can be reduced through engineering design. Aerodynamic noise depends upon rotor speed which varies with wind speed. Noise from the wind normally increases at a faster rate than the turbine noise."

3. quietrevolution noise objectives for the qr5

In the absence of a single clear standard which applies to an urban based wind turbine, **quietrevolution** have specified our own criteria for noise assessment based on the relevant aspects of the above noise standards as follows:

1. The wind turbine noise should not exceed 50 dB(A) L_{eq} for outside spaces. The 50 dB(A) L_{eq} level should only be for brief periods of time as a wind gust passes through the turbine and for relatively few hours per year.

2. As noise levels reduce by 15dB from inside to outside this would mean that the turbine noise levels would not exceed 35dB (A) L_{eq} within a property.

3. The majority of urban environments will have background noise well above 50dB. An increase of 5dB above background noise level would rarely be noticeable and should be considered as acceptable.

4. Sound propagation

Sound waves will propagate differently depending on the local environment. Without any obstruction from a single point noise source the sound pressure level ("**SPL**") will generally halve (reduce by 6 dB) as distance doubles, as sound is dispersed over a larger and larger area.

However spherical propagation must be modified when disruptive or reflective surfaces are present. (See further Beranek and Vers (1992)[6] which discusses propagation in more detail)

Sound propagation is affected by many factors including:

- Source characteristics such as: directivity and height.
- Absorption by the air – this is frequency dependent.
- Ground effects and shape of the land (reflection and absorption of sound on the ground, dependent on terrain cover, ground properties, frequency, buildings, trees, hedges, walls etc.).
- Blocking of sound by obstructions and uneven terrain.
- Weather effects (wind speed, change of wind speed or temperature with height).

The wind-generated contribution to background sound tends to increase fairly rapidly with wind speed. For example, during a sound assessment for the Madison (NY) Windpower Project, a project in a quiet rural setting, the background sound was found to be 25 dB(A) during calm wind conditions and 42 dB(A) when the wind was 5.4 m/s[7].

We therefore conclude that:

- Sound propagation in urban environments is complex and site specific.
- Background noise levels increase significantly as the windspeed rises and it is likely that the rate of increase will be very similar to, or greater than, the increase in the noise immitted by the turbine as rotational speed increases.
- A background noise level measured on a specific site at a low speed will be far lower than a noise level measured at the same location at higher wind speeds.

quiet**revolution** have developed an ongoing technical programme to monitor and measure background noise levels on a variety of sites (rural, suburban and urban) and would welcome independently verifiable data sets that have measured both noise levels and wind speed at known locations. quiet**revolution** would equally be happy to share our findings in due course.

5. Summary of noise survey on qr5 turbine

This section summarises the findings of the ISVR[11] Consultancy Noise Measurement Report ref. 7837-R01 conducted on the qr5 v1.2 VAWT dated 20th December 2007. The site used was specifically chosen because of its extremely low levels of background noise.

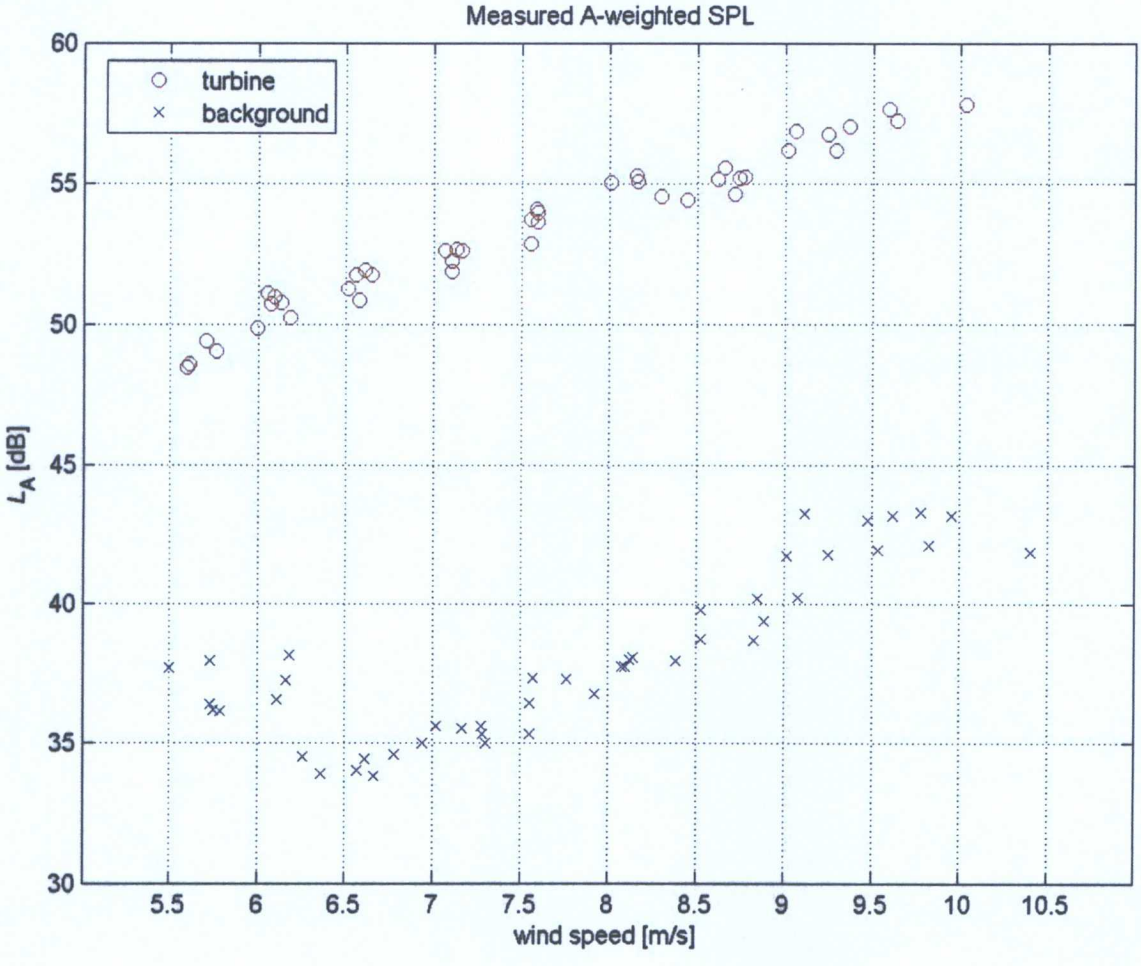
(Please see Appendix 1 for a brief description of the site and equipment used).

Taking data from ISVR's report, the measured equivalent sound pressure level is 57.9 dB(A) at 10 m/s wind speed at a distance of 22.5m from the rotor to the observer.

This measurement equates to an equivalent sound pressure level in free field conditions* of 51.9 dB(A) when the rotor is in a 10 m/s wind speed and the observer is at a distance of 22.5m from the rotor and 48.2 dB(A) when the observer is 35m from the rotor.

* See notes below graph.

Measured A-weighted Sound Pressure Levels for the qr5 turbine



The graph above shows the measured A-weighted sound pressure levels of the qr5 turbine compared to background noise levels at our test site in Pembrokeshire. This site was chosen as it is a site of very low background noise, situated away from noise sources including roads, trees, dwellings, industry etc.

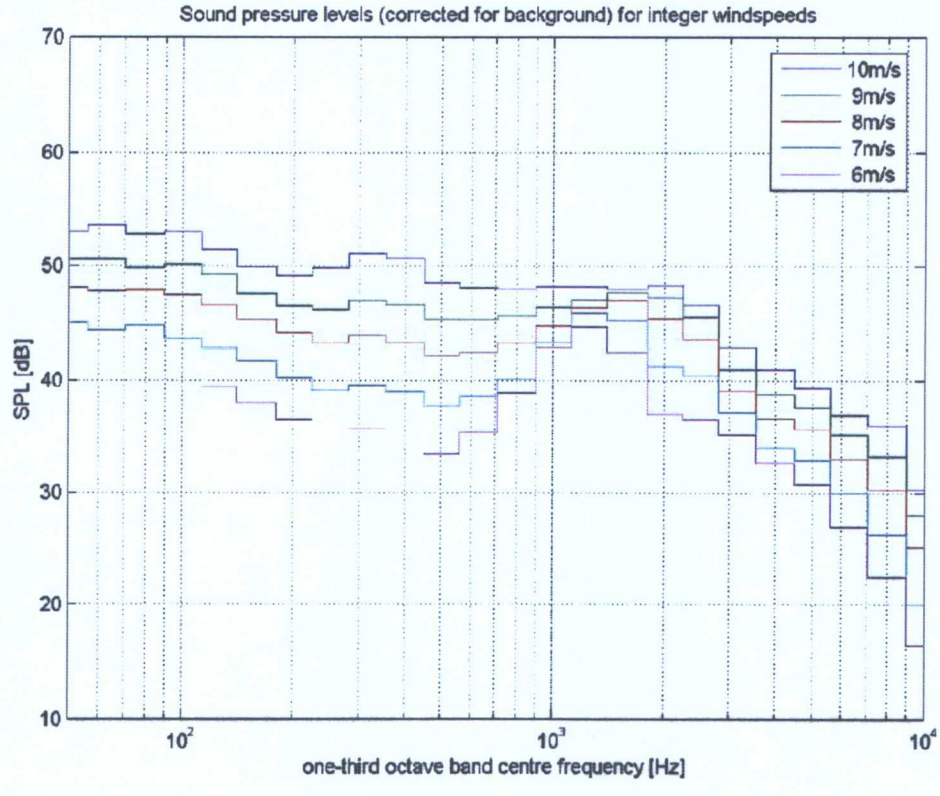
Notes

1. Noise measurements were taken at wind speeds of 6 – 10 m/s, in accordance with *BS EN 61400-11: 2003.*
2. The quoted equivalent sound pressure levels in free field conditions have been adjusted in accordance with *BS EN 61400-11* section 8.3, where a ground board is used to provide a controlled (6 dB) reflection.
3. The 6 dB constant accounts for the approximate pressure doubling that occurs for the sound level measurement on a ground board

Tonality

BS EN 61400-11: 2003 sets out criteria for the determination of whether there is a tonal element to the noise spectra at measured wind speeds. This would show up as a conspicuous peak in the sound pressure levels graph shown below, indicating an undesirable tone.

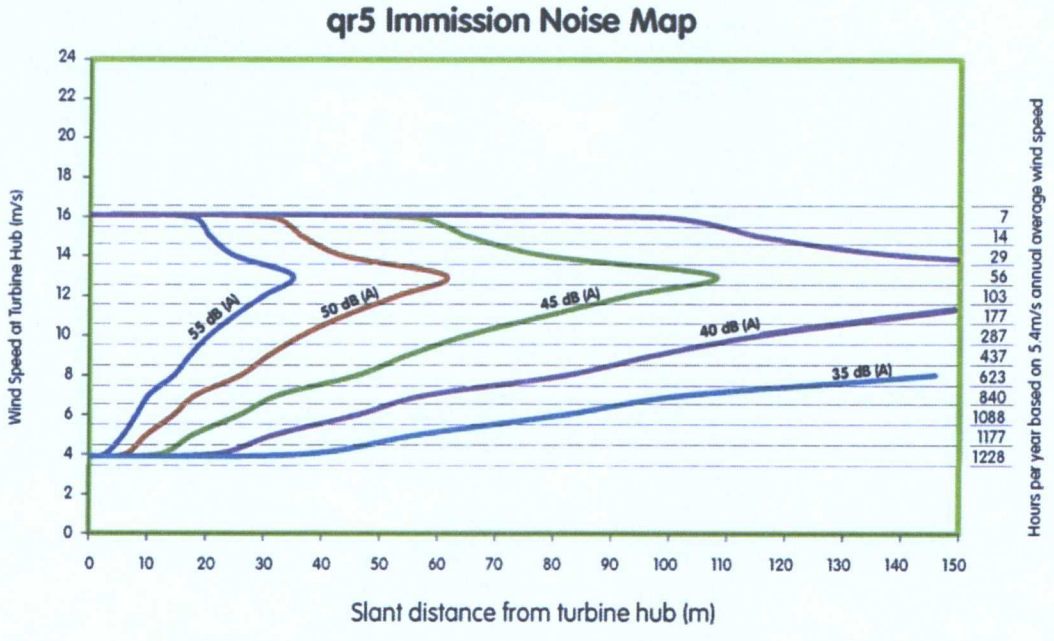
Application of the tone criteria as set out in BS 4142 demonstrated that the qr5 turbine noise was NOT tonal and therefore no sound penalty should be applied.



The one third octave band spectra, corrected for background noise, for integer wind speeds of 6 to 10 m/s.

Turbine Immission Noise Map

The graph below shows equivalent sound pressure levels at various distances from the turbine.



*Produced by quiet**revolution** from data contained within ISVR's report.*

Please note: these are external noise levels and allowances should be made for sound reduction across the threshold of an open window (typically 15 dB (A)). Propagation has been considered uniform and spherical and no allowances for obstructions such as trees, buildings etc. have been made.

It can therefore be concluded that if a qr5 turbine is greater than 35m away from an open window, noise levels inside a building would never exceed the recommended 45 dB(A) (as per *BS 8233: 1999*) nor our own recommended maximum levels of 40 dB(A), even with no other background noise such as traffic, machinery, vegetation, people.

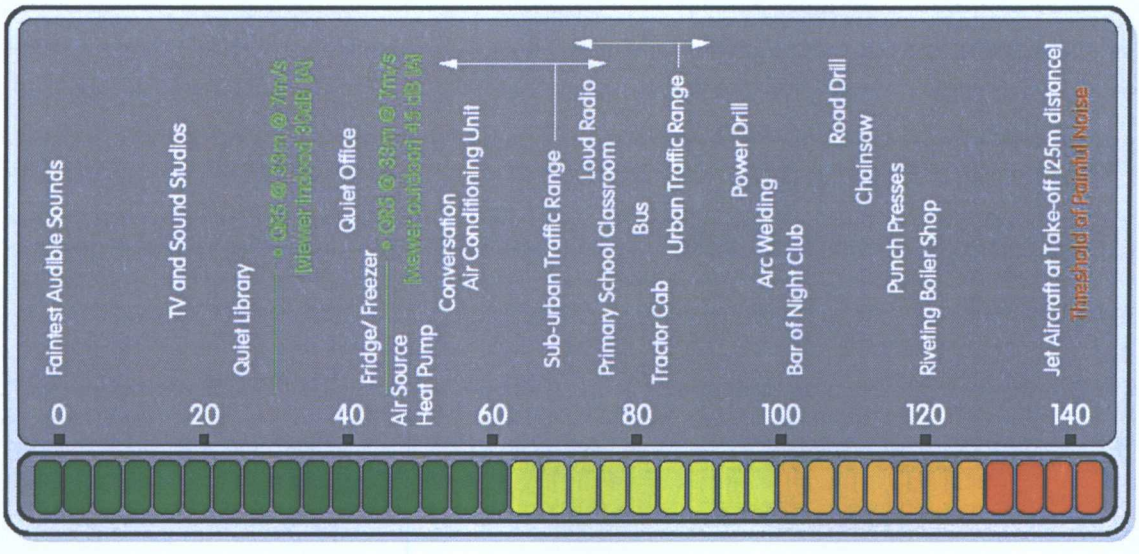
If a turbine is 20 to 35m away from an open window, it would only exceed 45dB (A) when wind speeds were between 10 and 16m/s which would be less than 7.7% of the year on a typical site with an annual mean windspeed ("**AMWS**") of 5.4m/s. Based on a 24 hour day, it is likely that approximately two thirds of the higher wind speeds will occur during waking hours and only one third during the night or 2.6% of the year. In addition the higher winds are often associated with cold or adverse weather when windows are likely to be closed and other external sources of wind noise have also risen significantly.

In conclusion: noise disturbance is a function of the ambient background conditions and the sensitivity of the observer. However in most environments and even when a QR5 turbine is sited close (20m) to a noise sensitive location, the risk of disturbance from a QR5 turbine is small.

6. Comparisons with other noise sources

To provide some points of comparison for the noise levels in question, please find below a table of typical noise levels in dB (A). Heard through an open window at a distance of 40m, a qr5 wind turbine would therefore sound about as noisy as a fridge freezer, and much quieter than an air conditioning unit.

Primary source of information: www.hse.gov.uk/noise/advise.html.



7. Sources of noise complaints

In practice road traffic and neighbours are most commonly cited as the most common source of noise complaints.

Source of information: *Royal Borough of Kensington & Chelsea.*

Residents were asked to rank the top five most annoying noise sources. The table below details the score for each source of noise.

Noise Source	**score**
- Road traffic	1912
- Building, construction, demolition, renovation or road works	1747
- Neighbours inside their homes, e.g. parties, music	1385
- Aircraft	1127
- Other people nearby	707
- Other entertainment or leisure, e.g. pubs, restaurants	522
- Any other noise	381
- Other commercial premises (including refuse collection from premises)	343
- Trains or railway stations	336
- Community buildings, e.g. churches, community centres	172
- Sports events	116
- Factories or works	100
- River or canal work	46

Appendix No.1

quiet**revolution** initially conducted a noise survey on the qr5 wind turbine in early 2007. This was undertaken at our Research and Development site in Membury, Berkshire where the background noise levels exceeded the measurable turbine noise at all wind speeds due to the proximity of the M4 motorway 250 metres away i.e. the turbine could not be measured by an observer standing 20m away above the noise of motorway traffic 250m away.

For this reason quiet**revolution** opted to re-measure the noise produced by the qr5 turbine at a remote location.

Site Description
The wind turbine tested was a qr5 v1.2 on a 15m mast. The noise survey was undertaken during November 2007 at Castlemartin Range, Pembrokeshire, a site predominantly of cut grass, with no reflective surfaces close to the measurement site and with very low background noise levels. Measurements were taken in accordance with *BS EN 61400-11: 2003 – Wind turbine generator systems. Acoustic measurement techniques.*

Measurement Locations
The measurements were taken using 4 microphones, in accordance with BS EN 61400-11: 2003. The reference microphone was positioned upwind of the turbine, at a distance of 22.5m from the base of the mast. Additional microphones were positioned as described in BS EN 61400-11 so that an analysis of directivity and tonality could be performed.

Measurement
The A-weighted sound pressure levels were recorded over 1 minute intervals, both with the wind turbine operating and with background levels only (i.e. with the wind turbine turned off).

Equipment
Measurements were taken using Bruel and Kjær equipment and calibrated to national standards. Corrections for background noise were made for both one-third octave band levels and overall A-weighted levels.

Additional Notes
The turbine tested was experiencing a once per revolution rubbing sound. quiet**revolution** have since investigated the source of this sound and corrected the problem. quiet**revolution** intend to repeat the noise tests in the near future and re-publish this report. The noise levels measured and reported are considered to be a worst case scenario.

In addition ISVR consultants observed that:

"There were no significant low frequency components, with no discernible whine, hiss, hum, clatter, click or thumping."

- Refer to tonality section above – therefore no tonal penalty should be applied.

References

[1] World Health Organisation ("WHO") Guidelines for Community Noise. http://www.who.int/docstore/peh/noise/guidelines2.html

[2] BS 4142: 1997 – Method for rating industrial noise affecting mixed residential and industrial areas

[3] BS 8233: 1999 - Sound Insulation and Noise Reduction for Buildings - Code of Practice

[4] Planning Advice Note: PAN 56: Planning and Noise – April 1999 (http://www.scotland.gov.uk/library/pan/pan56-00.htm)

[5] ETSU-R-97 - The Assessment and Rating of Noise from Wind Farms (written by a Noise Working Group established in 1995 by the Department of Trade and Industry through the Energy Technology Support Unit.

[6] Rogers, A et al (2002, amended 2006), "Wind Turbine Acoustic Noise", White Paper, Renewable Energy Research Laboratory, Department of Mechanical & Industrial Engineering, University Massachusetts at Amherst, MA 01003, USA

[7] Beranek, L. L. and Ver, I. L. (1992), Noise and Vibration Control Engineering: Principles and Applications, Wiley, New York

[8] Migliore, P et al (2004), "Acoustic Tests of Small Wind Turbines", AIAA-2004-1185, National Renewable Energy Laboratory, National Wind Technology Centre, Colorado 80401, USA

[9] Noise at Work – Health and safety in the workplace – March 2008 http://www.hse.gov.uk/noise/

[10] Brüel & Kjær Sound & Vibration Measurement A/S (2001), "Environmental Noise"

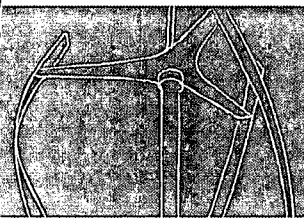
[11] Institute of Sound and Vibration Research, University of Southampton, University Road, Highfield, Southampton, S017 1BJ www.isvr.soton.ac.uk

Definitions

'A' frequency weighting	Frequency dependent correction that is applied to measured or calculated sound of moderate intensity to mimic the varying sensitivity of the human ear.
dB	Decibel, logarithmic unit of sound pressure.
$L_{A\,eq}$	A widely used noise parameter that calculates a constant level of noise with the same energy content as the varying acoustic noise signal being measured. The letter "A" denotes that the A-weighting has been included and "eq" indicates that an equivalent level has been calculated. Hence, $L_{A\ eq}$ is the A weighted-equivalent continuous noise level[10].
$L_{A\,max}$	Maximum A-weighted noise level. They are the highest level of environmental noise occurring during the measurement time. They are often used in conjunction with another noise parameter (e.g., $L_{A\,eq}$) to ensure a single noise event does not exceed a limit.
Sound Exposure Level (SEL)	A parameter closely related to $L_{A\ eq}$ for assessment of events (aircraft, trains, etc.) that have similar characteristics but are of different duration. The SEL value contains the same amount of acoustic energy over a "normalized" one second period as the actual noise event under consideration.
Sound power	The acoustic power radiated from a sound source. This power is essentially independent of the surroundings, while the sound pressure depends on the surroundings (reflecting surfaces) and distance to the receiver.
Noise immission	Sounds impacting on the human ear.
Noise emission	Sounds generated from all types of sources.
Tonality	The presence of tones in the noise at different wind speeds shall be determined on the basis of a narrow band frequency analysis as follows: • The sound pressure level Lpt of the tone shall be determined. • The sound pressure level of the masking noise Lpn in a critical band around the tone shall be determined. • The tonality DLt n, the difference between the sound pressure level of the tone and the masking noise level shall be found.

APPENDIX C

Qr5 – The relationship between background noise levels and acoustic impact



quietrevolution

The relationship between background noise levels and acoustic impact of the qr5 wind turbine

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The relationship between background noise levels and acoustic impact of the qr5 wind turbine.

INTRODUCTION

To date there is no singularly accepted standard or set of guidelines that advise how to assess the likely impact of wind turbines on noise sensitive locations. The Sustainable Development Commission report, "Wind Power in the UK May 2005" states "there are a number of guidelines that are used to determine acceptable levels of noise, such as:

- The World Health Organisation's (WHO) publication 'Guidelines for Community Noise'[1].
- The British Standard BS 4142, which offers a well-understood framework for measuring all industrial noise [2].
- A report produced for the DTI, "The Assessment and Rating of Noise from Wind Farms", describes a framework for measuring wind farm noise and offers indicative acceptable noise levels for developments [3]. "

The guidelines and standards generally agree that a noise source that is 5dB above background will rarely impact on peoples quality of life, while 10dB above background is likely to have an impact, giving rise to loss of sleep or other unwanted disruption.

It is generally accepted that when background noise levels are low (i.e. below 37dBA, a noise level produced by a specific source of greater than 45dBA is likely to be problematic[3]. However, wind turbines rarely operate at low wind speeds, which is when background noise levels are at their lowest. It is clear from what published data exists [4], [5], [7] that background noise levels increase significantly with increases in wind speed.

KEY ISSUES

1) In low wind conditions, background noise from the effects of the wind and the noise produced by wind turbines are both very low. The wind turbine in question may even be stationary.

2) As wind speed increases, both background and turbine noise levels increase.

3) Different wind turbines have different acoustic characteristics; some will produce higher noise levels than others over a range of wind speeds.

4) Some wind turbines exhibit 'tonal' characteristics during operation and these turbines are usually subjected to a 5dB acoustic penalty when assessing their likely impact [3]. The qr5 turbine has been specifically designed for use in close proximity to occupied buildings. Limiting acoustic impact and the avoidance of tonal characteristics has been a major consideration during the design and development of the qr5 turbine.

5) quiet**revolution** have undertaken an independent assessment of the QR5 turbine and it has been confirmed that NO tonal penalty should be applied [7].

6) The QR5 turbine is probably the quietest turbine available on the market of its size.

7) quiet**revolution** have installations that are mounted on-top of school classrooms and within 25m of noise sensitive locations. To date we have no reports of noise complaints for our turbines.

BACKGROUND NOISE LEVELS

In light of the widespread confusion over what noise levels are acceptable from wind turbines in the built environment, quiet**revolution** are seeking an independent research group to investigate and document how background noise levels rise as wind speeds increase on various typical sites. The goal being to publish a series of case studies as an aid to Planning Authorities in assessing an individual site, so that in many instances the expense of a site specific noise study can be avoided.

Background noise levels will vary greatly from location to location, items that effect the background noise level include: traffic; air conditioning and other plant; people; buildings; trees and bushes; construction; walls; and other obstructions.

In urban locations the main contribution to noise are: traffic, building plant, general construction, people and music.

In rural or suburban location the effects from trees, bushes, buildings, farming and animals are more likely contributing factors to background noise levels

It is known that background noise levels increase with increases in wind speed. The reasons for the noise increase are numerous, but in particular they are caused by objects with square corners such as buildings, signs, pylons etc and from objects that move with the wind such as trees.

The issue is how to determine for any particular site what the increase in background noise is likely to be as the wind speed increases.

The paper "Wind Turbine Acoustics" [6], states that background noise is "...an important factor in determining people's response to wind turbine noise (and) must be carefully accounted for in site measurements. Sources of background noise are the wind itself; its interaction with structures, trees, and vegetation; human activities; and, to a lesser extent, birds and animals. Natural wind noises are particularly important because they can mask wind turbine noise (the broadband spectra of both are the similar). Measuring background noise, at the same locations and with the same techniques used for measuring wind turbine noise, is an integral part of assessing receiver response."

The British Standard BS 4142 [2] states: "Because of the importance of background noise in determining the acceptability of the overall noise level, it is crucial to measure the background ambient noise levels for all the wind conditions in which the wind turbine will be operating. Sound propagation is a function of the source sound characteristics (direction and height), distance, air absorption, reflection and absorption and weather effects such as changes of wind speed and temperature with height."

Despite this, BS 4142 recommends noise measurements are undertaken in wind speeds of 0-5 m/s when the majority of small scale turbines would in fact not be operational.

From site specific measurements published in [4], [5], [7] and [8], background noise levels have been shown to increase by up to 25 dB over a wind speed range of 1.5 – 14.5m/s [8].

WORLD HEALTH ORGANISATION GUIDELINES [1]

The WHO guidelines indicate that a noise level of 45 dBA is the maximum that should be considered permissible from a man made noise source outside a noise sensitive location; this recommendation also assumes that the background levels are below 45 dBA. If the background levels are higher than 45 dBA then the impact from plant producing 45 dBA is low.

The WHO guidelines are a good guide when background noise levels are low. They are applicable for noise sources that are operating when there is little or no background noise, such as AC plant / air source heat-pumps etc.

Items of plant [AC / heat pumps etc.] tend to produce most noise when the air is still, hot and humid - conditions when windows will be open and people trying to sleep or enjoying external spaces would be disturbed. However the opposite is true of wind turbines as they produce their maximum noise levels when weather conditions are adverse and properties are more likely to have closed windows and people are indoors.

OUR AIM

Our aim is to gather independently corroborated data, relating wind speed to background noise levels, to confirm our expectations that for the majority of sites, background noise levels will increase either in tandem or faster than the increase in noise from the qr5 turbine.

We are confident that once a series of typical sites have been studied it will demonstrate that, if the qr5 turbine has no impact on noise sensitive properties at ~ 7m/s wind speed,

it is probable that it will also have no impact at higher wind speeds, despite the turbine being a source of greater noise at higher wind speeds.

EXAMPLES

The following table gives examples of background noise measurements to be expected at various typical sites. The collection of background noise data for typical sites shall be the subject of a further study [either by quiet**revolution** or in partnership with other organisations].

Wind speed	Likely background noise level [night-time] (dBA)			QR5 turbine noise level at 20m	QR5 turbine noise level at 35m	QR5 turbine noise level at 50m	likely impact on noise sensitive property
	Rural Village	Sub-urban	Urban				
2 m/s	32	36	40	0 dBA	0 dBA	0 dBA	None
4 m/s	38	42	46	0 dBA	0 dBA	0 dBA	None
7 m/s	44	50	54	48 dBA	45 dBA	42 dBA	Minimal and rare
10 m/s	54	60	64	56 dBA	50 dBA	47 dBA	Minimal and rare
13 m/s	60	66	71	61 dBA	55 dBA	52 dBA	None *[peak noise level from turbine]*
16 m/s	68	74	80	47 dBA	43 dBA	40 dBA	None
20 m/s	78	84	90	0 dBA	0 dBA	0 dBA	None

UNCERTAINTY

The only sure way of demonstrating whether the turbine noise is likely to impact on neighbouring properties is to assess the noise profile of the site at a variety of wind speeds and compare these to measured turbine noise levels for the same wind speeds.

The ideal location for setting up the measuring equipment is as close to as possible to the noise sensitive location.

Typically it takes 4-5 weeks from setting up equipment to the production of the report, however the data collection is weather dependant and a full range of wind speeds between 3m/s and 10m/s is ideal to properly assess the site.

It is usually not practical to assume that data from periods when wind speeds are higher than 10m/s can be collected as these higher wind speeds are rare and account for approx. 300 hours / year (<3.5%), or less, on a typical site [even 9m/s and 10m/s wind data may be difficult to collect depending on the weather conditions at the time of survey].

A typical cost for undertaking a background noise assessment, including a weather station measuring wind speed is IRO £1,500.00 to £3,000.00. and would typically take 2-4

weeks to collect the data, depending on weather and windspeeds.

To reduce the uncertainty level when undertaking acoustic surveys it is vital to follow existing standards and to use professional and calibrated equipment. quietrevolution have documents available on the methods for collecting noise and wind speed measurements.

CONCLUSION

Assuming a clear line of site between turbine and the noise sensitive location, quiet**revolution** anticipate that a turbine located at 35m distance or greater, would have minimal acoustic impact and the turbine is unlikely to be a problem.

In quiet rural or edge of town locations, at distance less than 35m the risk of adversely affecting noise sensitive locations begins to increase, however any trees, buildings or other obstructions located between the turbine and the noise sensitive location are likely to considerably reduce the impact of the turbine, either because the obstruction is itself a source of wind noise or due to the absorbing and defracting effects of the obstructions.

REFERENCES

[1] World Health Organisation "*Guidelines for Community Noise*" 1999

[2] BS 4142: 1997 – *Method for rating industrial noise affecting mixed residential and industrial areas*

[3] ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms*. ETSU for the Department of Trade and Industry, 1996

[4] McKenzie, A.R., Bullmore, A.J. and Flindell, I.H. 2002 *The effects of wind speed and direction on ambient and background noise levels in the suburban environment.* Proceedings of the Institute of Acoustics, 24, (3), 15-22.

[5] Ontario Ministry of the Environment, "*Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators.*" PIBS 4709e, 6 July, 2004.

[6] Hubbard, H.H. and Shepherd, K.P. "*Wind Turbine Acoustics*", NASA Technical Paper 3057 DOE/NASA/20320-77, December 1990

[7] quiet**revolution** Noise Statement for the qr5 wind turbine, June 2008, extract from ISVR Consultancy Report Ref. 7837-R01 "*Wind turbine noise measurements*".

[8] McKenzie, Dr A.R.: "*Background Noise Measurements for Wind Farm Noise Assessment", 2005,* Institute of Acoustics Wind Farm Noise.

APPENDIX D

Qr5- Shadow Flicker Statement

Comment on 'shadow flicker' and photosensitive epilepsy

Issued : November 2008
Revision : '0'

DEFINITIONS

Flicker:	A term used to describe inconsistent or wavering light.
Shadow flicker:	An effect that occurs when the sun is viewed through the rotating blades of a wind turbine

INTRODUCTION

quietrevolution are regularly asked to comment on 'shadow flicker'. However when we are asked to comment, there is rarely any definition of shadow flicker provided, nor is there any attempt to provide assessment criteria against which a reasonable evaluation could be made.

This commentary attempts to summarise the potential issues and dispel the myths. The assumption is that the effect of shadow flicker is experienced within a building, whether a dwelling, office or other building type.

HORIZONTAL VERSUS VERTICAL WIND TURBINES

At this stage the issue of reflected light for quietrevolution turbines is not considered to be a problem, as the twisted helix shape of the blades and the curved shape of other surfaces will disperse light rather than focusing it toward the viewer. The same may not be true of the majority of land based horizontal axis wind turbines, which have three or five blades; are often larger in scale; and commonly have flatter more linear faces which would have more of a potential to reflect light in a single direction causing a flickering affect to the viewer.

STANDARDS AND CASE STUDIES

There are as yet no British, European or International Standards for shadow flicker levels. This is because the perceived risk is too small and difficult to measure and the subject is complex with a large number of variables.

Despite the growing number of wind turbines installed worldwide, evidence of flicker effects is hard to find. Even in countries such as Germany, which is renowned for setting rigorous, demanding and thoroughly researched standards, there are no published standards and we can find NO examples of turbines causing photosensitivity related fits.

A rule of thumb, however, has been adopted [*and upheld by the German legal system*] that 30 hours of shadow flicker per year is acceptable[2]. This is based on those 30 hours being when:

i. The sun is shining
ii. The building effected is occupied
iii. The occupants are awake
iv. The turbine is spinning

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Other European countries such as Denmark and Holland with large wind industries follow similar guidelines to Germany, and there are no reported cases in any of these countries.

SUMMARY OF RISK

Based on the above rule of thumb, for shadow flicker to be an issue the following must all occur:

1. The sun must be shining [not behind cloud] *

2. The wind must be blowing at a speed sufficient for the wind turbine to be operational [for a quietrevolution turbine this is 4.5 to 16m/s] *

3. The flickering light must fill the majority of the field of vision.

4. There must be a person in the room and the person must be awake
   - For a bedroom this might only be, at most, 1 hour per day during the morning. Individual habits will vary but the hour is most likely to fall between 6.30-10am
   - For a living room the hours of occupation might be daylight hours [assuming that the occupants are not out at work
   - For a work environment, the hours of occurrence might typically be, between 8.30am and 6.00pm

5. There must be no curtains or blinds

* **Note:** *To estimate the number of hours where both the wind is blowing and the sun is shining a calculation is made. This calculation is termed "the de-rating factor". To determine the de-rating factor, historical meteorological data is used, In the UK the number of hours where both the wind is blowing and the sun shining is typically only 30% of daylight hours.*

PHOTOSENSITIVE EPILEPSY

The primary (and only real) cause for concern in relation to 'shadow flicker' is the risk of stimulating an epileptic fit in those who are susceptible to photosensitive epilepsy.

About 1% of the population suffer one or more epileptic fits during their lifetime. Of those who suffer from epilepsy only about 4% suffer with epileptic fits that are triggered by photosensitivity. This equates to approx. 23,200 people in the UK, or 0.04% of the population. In addition the specific trigger for any particular individual will vary.

The causes of a photosensitive epileptic fit are numerous [1], it is much more complex than simply flickering light. The factors include:

- DISTANCE: for wind turbines typically 10x rotor diameter is considered the limit of any potential problem, [the qr5 is equivalent of a ø4.2m HAWT] therefore a 42m limit is reasonable

(PAN 45 (Revised 2002) Renewable energy technologies, paragraph 64. '...where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters), 'shadow flicker' should not be a problem.

- FREQUENCY: 7Hz to 20Hz are considered to be the frequencies, where those at risk of photo sensitive epilepsy, are more likely to suffer a seizure. The frequencies 5Hz to 30Hz have a substantially lower risk and for frequencies outside these ranges the risk is minute.
  For information, quietrevolution's qr5 turbine CPS is 1.67Hz to 4.30Hz (100-260 RPM)

- COLOUR: The colour of the light is critical, deep red contrasted with other colours, especially blue, is known to have the worst affect. People who are susceptible to photosensitive epilepsy, due to colour contrast, often wear optical filters to dramatically reduce their risks.

- AGE: Photosensitive epileptic fits and far more common in the young than in adolescents and even less among adults.

- FIELD OF VISION: The amount of the individuals field of vision that is exposed to the light (e.g. A very large screen (or the viewer sitting close) with flashing lights is more likely to trigger a fit that a smaller screen (or the viewer at a greater distance). If the field of vision is less than 25% flicker light it is not generally a problem. For this reason a turbine in an external environment is never likely to cause a photo sensitive epileptic fit as the percentage of the field of vision occupied by the flickering light is always likely to be far below 25%.

- INTENSITY: or brightness of the light

- CONTRAST: Between the light and shadow (the greater the contrast the greater the risk). There will be far less contrast as the sun rises and sets than in the middle of the day.

- BACKGROUND LIGHT LEVELS. In a typical office environment the background light levels are normally high as large numbers of ceiling mounted fluorescent lights are usually permanently switched on during working hours. Offices also typically have blinds to filter and diffuse direct sunlight, as sunlight makes the viewing of monitors very difficult.

REPORTED OCCURRENCES

We have searched extensively in the UK and abroad for reported occurrences of shadow flicker actually causing a photosensitive epileptic fit or seizure, however we can find no reported occurrences anywhere and certainly no cases that have come to court or encouraged any legislative body to explore the possibility of writing a suitable standard.

There are pseudo-scientific papers that report on the potential risks, but these papers also do not site any examples where there have been photosensitive epileptic seizures or even reportable problems caused by shadow flicker from a wind turbine, these papers often include some fantastic quotable lines but do not back up their claims with evidence.

There are currently [Autumn 2008] approx. 9,000 small scale wind turbines installed in the UK, in locations from dwellings to schools, offices, factories etc., none of these turbines have to date caused a reportable incident of flicker induced epilepsy.

TO CONCLUDE

For a wind turbine to present a potential hazard to someone who is at risk from photosensitive epilepsy, **all** of the following must be true:

- The wind must be blowing.
- The sun must be shining.
- The observer must be close enough to the flickering light source to be affected
- The observer must be within in the flickering light field
- A large percentage of the individuals visual cortex must be stimulated [over 25%]
- The rotor must be spinning at a speed that affects the specific photosensitive range of the observer.
- The rotor spinning speed must stay in the specific range long enough to trigger a reaction.
- The background illumination must be low
- The contrast between shadow and light must be high
- The colour spectrum of the light must be in the correct range to affect the individual
- There is nothing blocking out the flicker light, such as blinds or a tree outside the window.
- The individual does nothing to remove themselves from the flicker light source before it begins to affect them.

Note: due to the constant movement of the sun through the sky, the amount of time a flickering source may fall on any particular place or window is likely to be less than 10-15 minutes on any particular day and if a location is susceptible in mid summer, it will almost certainly not be susceptible at other times of the year.

Therefore in the absence of any published standards or case studies, and on the basis of the above factors the risk is perceived to be very low and hard to measure, and therefore flicker or shadow flicker concerns should not be a reason for planning permission being refused for a wind turbine installation.

EXAMPLES

1 : A typical working office

Once the factors below are considered the risk of photosensitive epileptic fit occurring within an office environment has dropped well below the levels of other risks present in a typical workplace. Risks that are either highly unlikely or if occurring have only a minor impact can be managed in the same way as other minor office risks, such as, fire evacuation procedures, lifting and manual handling, first aid, trip hazards etc.

People in an office will be generally adults, the environment is likely to be low contrast, there are likely to be large windows (making the 25% field of vision occupied by a flickering source as unlikely). There are likely to be blinds if direct sunlight is ever a problem and the sun is likely to be high in the sky and therefore the shadows short, limiting the impact to a smaller area There will also be only a limited amount of time with both wind and bright sun.

Once the above factors are considered, if quantified, the number of people who might be affected in this environment are very small, perhaps 3000 people in the UK or perhaps 210 people working in offices in London.

SOURCES:

1. The National Society for Epilepsy, January 2007, (www.epilepsynse.org.uk)
2. http://www.windpower.org/en/tour/env/shadow/index.htm