9 Noise and Vibration

Contents

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9 Noise and Vibration

9.1 Executive Summary

9.1.1 This chapter evaluates the noise effects of the Revised Development. The levels of noise likely to occur at local residential properties as a result of the operation of the proposed turbines has been assessed. The Revised Development differs from the Consented Development in that there is no Wood Fuel Drying Plant, a biomass-fuelled CHP generation plant having been constructed instead, and there are thirteen (13) wind turbines with a slightly increased tip height, rather than the fifteen (15) in the Consented Development.

9.1.2 The noise and vibration assessment has been conducted on the basis that the noise limits in the planning conditions for the Consented Development would be applied without any significant changes applicable for the Revised Development. On that basis, the assessment concludes that the Revised Development will also meet all the conditions regarding noise and vibration contained within the extant permission for the Consented Development, and that there will be no detectable differences in terms of the noise immission between the two schemes. It is however proposed that condition 45 of the Consented Development (ref. CL/15/0273) be amended to recognise the fact that the properties at Westerhouse and Station House are financially involved in the Revised Development and the applicable noise limits should therefore reflect this (see Table 9.4 below).

9.1.3 The conclusions to the noise assessment below are therefore the same for the Revised Development as those reached for the Consented Development: it is anticipated that there will be no significant residual effects on nearby residential properties as a result of the construction and operation of the Revised Development.

9.2 Introduction

9.2.1 Background noise levels were surveyed in July 2012 and assessed in connection with an earlier proposed scheme on behalf of previous developers Community Windpower Ltd. The results of the 2012 survey were acquired by the Applicant and were considered appropriate for use in the 2015 application, but a further campaign of background noise measurements was undertaken at a single location during April 2015 in order to verify the previous results, as agreed with the South Lanarkshire Council (SLC) Environmental Health Department (refer to Appendix 4.4).

9.2.2 The 2015 assessment was made against the guidelines available for wind energy developments as noted in Section 9.2.5 below. Particular attention was paid to the ETSU-R-97 report *The Assessment and Rating of Noise from Wind Farms*, the latest *Onshore wind energy planning conditions guidance note* (Renewables Advisory Board and the Department for Business, Enterprise and Regulatory Reform, BERR) and the Institute of Acoustics' (IOA) *Good Practice Guide on the application of ETSU-R-97*, May 2013 together with its supplementary guidance notes published in 2014.

9.2.3 The background noise surveys were carried out in accordance with best practice guidance for wind energy schemes in order to assess the likely impact of the wind turbine generators on noise-sensitive receptors. Planning conditions were set by SLC when planning permission was granted for the previous (2015) scheme and the wood fuel drying facility associated with it. The development now proposed consists solely of wind turbines and their associated infrastructure, so the noise limits and conditions previously set down are appropriate for the protection of nearby receptors (subject to recognising the financial involvement of Westerhouse and Station House as explained in paragraph 9.1.2 above). Removal of the wood fuel drying facility included in the previous application had no impact on the outcome of the wind farm noise assessment.

9.3 Legislation, Policy and Guidelines

Legislation

9.3.1 The Control of Pollution Act 1974 sets out legislation relating to noise from construction sites, from plant and machinery and from other sources, and discusses Best Practicable Means and codes of practice for minimising noise.

Policy

9.3.2 Energy policy in Scotland has been specifically reserved to the UK parliament, but planning is a matter that has been devolved to the Scottish Parliament. The Scottish Government has previously stated that ETSU-R-97, supplanted by guidance on best practice, should be used to assess environmental noise from wind turbines (Scottish Government, 2014).

9.3.3 Chapter 5 sets out the planning policy framework that is relevant to the EIA. Of relevance to the noise and vibration assessment presented within this chapter, regard has been had to Paragraph 169 of Scottish Planning Policy, which notes that noise impacts on individual dwellings and communities are to be considered in development management for energy developments.

9.3.4 Relevant SLC policy relating to assessment of noise from onshore wind farms is found in the South Lanarkshire Local Development Plan (2015), and SLC Supplementary Guidance 10 Renewable Energy (2015). Part 10b of the assessment checklist (Table7.1) also states that "*all applications for wind turbine developments should be accompanied by a site specific noise assessment*".

Guidance

9.3.5 Recognisance has been taken of the following guidance and recommendations:

- The Working Group on Noise from Wind Turbines The Assessment & Rating of Noise from Wind Farms (ETSU-R-97) (1996)
- (Institute of Acoustics, 2013) Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise (IOA Good Practice Guide) and associated Supplementary Guidance Notes
- Planning Advice Note (PAN) PAN1/2011 Planning and Noise. Information and advice on noise impact assessment methods is provided in the associated Technical Advice Note Assessment of Noise
- (Institute of Acoustics, 2009) Bulletin Article Volume 34 No. 2, March / April 2009
- ISO 9613-2:1996 Acoustics -- Attenuation of Sound during Propagation Outdoors -- Part 2: General Method of Calculation

9.4 Consultation

9.4.1 The Environmental Health department at SLC was consulted before the original background noise survey in July 2012 was carried out, in connection with the previous proposals for the site on behalf of Community Windpower Ltd. The Environmental Health Officer (EHO) was consulted again in 2015 in order to discuss the scope of any further background noise survey work and whether the results of the 2012 survey could still be considered valid. As a result, it was agreed that background noise measurements should be repeated at a single location to validate the 2012 results (refer to Appendix 4.4). Subsequently, a further campaign of background noise measurements was carried out at a single location in March/April 2015, being a repeat of part of the 2012 work.

9.4.2 Through consultation with the Environmental Health department it was considered neither necessary nor advisable to repeat the background noise measurements at other locations because additional turbines had since been brought into operation. Further wind turbines have been brought into operation since 2015 so additional background noise measurements were not appropriate.

9.4.3 The repeat measurements undertaken also served to validate the wind speed measurements used in the analysis of the 2012 data, since these were conducted at 10 m height and long-term data used to allow for wind shear. The 2015 survey used wind speed measurements from a 50 m tall meteorological mast on the site in accordance with the IOA Good Practice Guide, published in the interim.

9.5 Assessment Methodology and Significance Criteria

Study Area

9.5.1 Preliminary noise predictions for a matrix of thirteen 3.6 MW turbines indicated the area within which a noise immission level of 35dB $L_{A90,10min}$ could be exceeded. The extent of this area depends on the disposition of the nearest turbines to the receptor in question, and the area possibly affected by noise from the Revised Development could extend to 5 km from the site boundary, although at such distance the noise immission level will be considerably less than 35 dB. The nearest noise-sensitive receptors within the study area which could be subject to more than approximately 30 dB were identified so that noise predictions could be made for all residential properties in accordance with the relevant guidance. It is worthy of note that in any given direction from the Revised Development, if the noise impact is acceptable at the nearest noise-sensitive location then it must necessarily also be acceptable at more distant locations.

9.5.2 Given that the separation distances between the Revised Development and the nearest residential properties are of the order of hundreds of metres, vibration effects would be imperceptible, so only a brief qualitative vibration assessment was conducted. The levels of vibration depend not only on the input excitation, but also on the ground conditions close to the surface (in the unconsolidated layer) and the nature of the property in which vibration might be detected. None of these can be predicted other than in terms of the order of magnitude.

Methodology

PAN45 and Subsequent Web-based Guidance

9.5.3 Until early 2011 Planning Advice Note 45 specified the issues that should be taken into account by local planning authorities when assessing the development of renewable energy projects. Regarding wind turbines in particular, the guidance stated that the framework for the measurement of wind farm noise in the ETSU-R-97 report (see below) should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from such developments, until such time as an update was available. PAN 45 also cited the UK Government's statement regarding the findings of the Salford University report into aerodynamic modulation of turbine noise, which concludes that there is no evidence of health effects arising from infrasound or low frequency noise generated by turbines.

9.5.4 In March 2011, PAN 45 was revoked and replaced by web-based planning guidance on renewable energy. This web-based guidance refers to ETSU-R-97 as a framework for the measurement of wind farm noise which should be followed by applicants and consultees, and used by planning authorities to assess and rate noise from wind energy developments, until such time as an update is available. It goes on to cite ETSU-R-97, stating that it *"…gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable burdens on wind farm developers, and suggests appropriate noise conditions"*.

ETSU-R-97

Background noise

9.5.5 A development of this type should be assessed using ETSU-R-97, since the current web-based guidance recommends this approach. The report describes a framework for the measurement of turbine noise and indicates desirable noise levels, so that without placing unreasonable restrictions on wind energy developments, neighbouring residential properties can be protected from excessive noise. A primary objective of the report is to suggest noise limits in a form suitable for adoption as

planning conditions. The Noise Working Group that produced the report considered that absolute noise limits regardless of wind speeds were not suited to wind energy schemes in the UK, and that it was more appropriate in the majority of cases to set noise limits relative to background noise.

9.5.6 The background noise levels are to be measured over a range of wind speeds so that the impact of turbine noise, which is also wind-speed dependant, can be evaluated. The parameters to be measured include the equivalent continuous noise level and the 90 % exceedance level. The equivalent continuous noise level L_{Aeq} is the noise level in 'A' weighted decibels which, if present for the entire measurement period, would produce the same sound energy to be received as was actually received as a result of the real, time-varying signal. The abbreviation often includes a specification of the time period (such as 1 hour, or 5 minutes) indicating the period of time to which the measured value has been normalised; for example, '$L_{Aeq,1h}$'.

9.5.7 The statistical indicator of the form L_n resulting from an environmental noise measurement is the level which was exceeded for *n* percent of the measurement period. Thus, an L_{A90} of 40dB means that an A-weighted sound pressure level of 40dB was exceeded at the microphone for 90% of the measurement period. Any value of *n* between 0 and 100 is meaningful, but the indices most widely used in the UK are L_{A90}, L_{A50} and L_{A10}. The L_{A90} index is generally taken to be representative of the steady background noise level. The L_{A50} is the arithmetic average of all the instantaneous values during the measurement period. The principal use of L_{A10} is in the assessment of road traffic noise. Again, the time period over which the measurement took place can be specified, so the $L_{A90,10min}$ is the level which was exceeded for 90 % of a ten-minute measurement period: in other words, the level was exceeded for nine of the ten minutes.

9.5.8 One of the most important recommendations in the ETSU-R-97 report is that the statistical index $L_{A90,10min}$ should be used for both the background noise and the wind farm noise. This allows reliable measurements to be made without them being corrupted by louder, transitory noise events from other sources, which would be unavoidable in the countryside. The report notes that for a typical turbine the $L_{A90,10min}$ is between 1.5 and 2.5dB lower than the L_{Aeq} over the same measurement period. This is worthy of note because for conventional noise measurements in the environment, the L_{Aeq} index is generally regarded as the most appropriate descriptor, and it is normal practice to use it when noise limits are being set. In the present assessment, a constant difference of 2dB between the $L_{A90,10min}$ and the L_{Aeq} is assumed.

9.5.9 A methodology is provided in ETSU-R-97 for the measurement of background noise levels under various wind conditions. The report recommends that data which may be corrupted by extraneous noise sources, including periods when rain falls or when watercourses have abnormally high flows, should be discarded. At all times, the noise levels measured in the environment are to be correlated with wind speed measurements at the site, at a reference height of 10 m above ground. Because the noise levels can vary by several decibels at any given wind speed, a curve is to be fitted to the raw data (having discarded measurements that were possibly rain-affected, as noted above) in order to determine the typical variation in background noise level with wind speed. The exercise is carried out for 'quiet' daytime amenity periods and night-time periods, defined as follows. Daytime amenity periods are from 18:00h to 23:00h on weekdays, 13:00h to 23:00h on Saturdays, and all day Sunday. Night-time is between 23:00h and 07:00h daily. All other periods (weekdays and Saturday mornings) are defined as normal daytime, when it would be expected that the ambient noise levels may be somewhat elevated because of human activity, distant road traffic, and natural noise sources.

9.5.10 No specific method is prescribed for the calculation of turbine noise, although there is a basic requirement for the sound power level of the machine to be determined by a standard test method (such as the IEA Recommended Practice). It should be noted that background noise levels are to be determined by best-fit curves through the survey data once extraneous data points have been removed. The ETSU-R-97 report has been supplemented with good practice guidance published by the IOA; this is described below.

Noise Limits

9.5.11 The practice of controlling turbine noise by means of noise limits at the nearest noise-sensitive properties is appropriate to the Revised Development, and this was the practice adopted when the

existing planning conditions for the Consented Development (15-turbines) were set. Noise limits are applied at external locations and only to those areas frequently used for relaxation or activities for which a quiet environment is highly desirable. Noise limits were set relative to the background noise at the nearest noise-sensitive properties. Thus, the limits reflect the variation in both turbine source noise and background noise with wind speed. According to ETSU-R-97 and RAB/BERR guidance, separate noise limits are appropriate for daytime and for night-time, because during the night the emphasis is on preventing sleep disturbance rather than protecting external amenity. Absolute noise limits and margins above background relate to the cumulative effect of all turbines in the area contributing to the noise received at the properties in question. Noise from the turbine or combination of turbines is limited to 5dB above background for daytime and night-time, remembering that the background level of each period may be different.

9.5.12 The process by means of which the noise limits were reached is described for completeness in the following section.

Guidance on the use of ETSU-R-97

Acoustics Bulletin Article

9.5.13 After some years of applying the ETSU-R-97 recommendations, there was a perceived need to update the guidance in order to keep it relevant to modern large turbines. A panel of acoustics practitioners in the field held a number of discussions, the product of which was an agreed procedure published in *Acoustics Bulletin* in the March/April 2009 issue (volume 34, number 2). In the six years between the appearance of that publication and the date of this planning application, two enhancements or clarifications of ETSU-R-97 in the article have received widespread acceptance among local planning authorities and at Public Inquiries into wind farm applications. The enhancements relate to *(i)* the issue of site-specific wind shear and *(ii)* the assumptions to be made when predicting turbine noise at remote locations. These topics are also dealt with in the IOA Good Practice Guide.

IOA Good Practice Guide (2013)

9.5.14 The IOA Good Practice Guide includes a number of important recommendations, many of which originally appeared in the *Acoustics Bulletin* article of March/April 2009. The guide presents current good practice in the application of the ETSU-R-97 assessment methodology for all wind turbine developments above 50 kW, reflecting the original principles within that guidance and the results of research and experience since its 1996 publication. The document was prepared by an IOA working group but further comments were received from the relevant UK Government Oversight Group at DEFRA and absorbed into the Guide.

9.5.15 As far as the Revised Development is concerned, the Guide is particularly relevant to the consideration of turbine noise emission characteristics (noise input data) and to the determination of background noise levels and wind speeds, and thus noise limits. A method of allowing for wind shear in situations where a full height meteorological mast is not available is also recommended in the Guide. Summary points are provided as numbered Summary Boxes (SB): those relevant to the present study are provided below with explanation. Additional supplementary guidance notes, published separately, expand on some of the aspects considered.

9.5.16 SB2 states that the study area should cover at least the area predicted to exceed 35dB L_{A90} at up to 10m/s wind speed from all existing and proposed turbines. There is no requirement to consider noise levels at wind speeds above 10 m/s because the subject turbine reaches its maximum noise output at a lower wind speed than 10 m/s (derived at 10 m height), and its wind speed versus noise characteristic reaches a plateau level. SB3 requires that any contribution to background noise levels from an existing wind farm must be excluded when assigning background noise and setting noise limits for a new development.

9.5.17 SB4 relates to the selection of background noise monitoring locations. SB6 confirms that surveys may be carried out at any time of year. SB7 dictates the standard of measurement equipment to be used, and SB8 informs the choice of measurement locations. SB9 requires the correlation of noise

measurements with standardised 10 m wind speed, and SB10, SB11 and SB12 give further recommendations for the conduct of background noise surveys and their duration.

9.5.18 SB13 confirms that the definitions of 'amenity hours' and 'night-time hours' in ETSU-R-97 remain applicable. SB14 requires the removal of data showing the presence of noise sources 'not common to the representative measurement locations', and SB15 recommends that the 'dawn chorus', where present, should also be removed from the data set. SB16 formalises the removal of rain-affected data, and SB17 allows the routine inclusion of noise from rush hour traffic. SB18 is a recommendation for data analysis by regression but states that the order of that regression depends on the nature of the noise environment.

9.5.19 SB20 deals with the prediction of noise immission levels from wind turbines. In summary, it confirms the recommendations of the *Acoustics Bulletin* article of March/April 2009 in respect of the difference between L_{A90} and L_{Aeq}, the adoption of a ground factor *G* of 0.5, the inclusion of a margin of uncertainty in the turbine noise emissions, together with a statement of its robustness, and the basic parameters for source and receiver heights and atmospheric conditions.

9.5.20 SB21 describes the issues in cumulative noise assessment, where a new wind energy development is proposed in an area where one or more turbines are already operational or proposed.

9.5.21 Under Section 7, Other Guidance, the IOA Guide covers points including planning conditions, (of which a sample is provided), and states that the evidence in relation to 'excess' or 'other' amplitude modulation (AM) is still developing. At the time of writing, current practice is not to assign a planning condition to deal with AM, because it has not proved possible to develop a workable and valid form of condition. An IOA Working Group has recently defined a metric for the detection and definition of AM but has not given any indication as to how the findings might be incorporated into planning conditions.

9.5.22 Six Supplementary Guidance Notes are referred to in the IOA Good Practice Guide. Four of these were published in July 2014, and the other two in September 2014. Supplementary Guidance Notes numbers 1 to 4 inclusive are applicable to the present assessment: they relate to data collection, sound power level data, data processing and filtering, and the derivation of wind shear.

Significance Criteria

9.5.23 Predicted noise levels which exceed relevant limits at noise-sensitive receptors, calculated by the above methodology, are considered to be significant. Noise levels which do not exceed the relevant limits at noise-sensitive receptors are not significant.

9.6 Background Sound Measurements and Noise Limits

Dates

9.6.1 A number of site visits took place both in 2012 and 2015 in order to gain an understanding of the area around the site, to select background noise measurement locations, to obtain the consents of landowners where necessary, and to place, service and retrieve survey equipment. The first noise survey campaign (three locations) began on Tuesday 03 July 2012 and was completed on Wednesday 01 August 2012. The second noise survey began on Thursday 26 March 2015, although wind data did not become available until Monday 30 March. The survey was completed on Monday 27 April 2015. In both cases approximately four weeks' worth of usable data were successfully collected.

Instrumentation

9.6.2 The instruments used for automatic noise monitoring during both survey campaigns were Rion NL-32 or NL-52 data logging sound level meters, each fitted with a type UC-59 condenser microphone and a shower-proof outdoor windshield assembly with a double screen. The microphones were mounted on robust stands at a height of 1.2 metres above ground. Each sound level meter was powered by high-capacity battery packs, housed with the meter in a sealed weatherproof case to prevent tampering. Ambient noise levels expressed in the form of $L_{A90,10min}$ values dB were recorded

continuously 24 hours a day throughout the survey period. The results were downloaded to a laptop PC at the end of the survey. Details of all instruments are shown in Table 9.1.

Table 9.1 – Noise Measuring Equipment

Meter	Serial numbers of meter, microphone	Calibrated by, date	Deployed at
Rion NL-32	1193084, 315704	ANV, 16 January 2012	N1 Westerhouse
Rion NL-32	103137, 316490	ANV, 2 February 2012	N2 Station House
Rion NL-32	1182906, 315425	ANV, 24 January 2012	N3 6 Middlemuir Road
Rion NL-52	121670, 318723	ANV, 23 July 2014	N1 Westerhouse (2015)

9.6.3 The calibration of the instruments was checked before and after the measurements using a Bruel & Kjaer type 4231 electronic calibrator, serial no. 1934427. No calibration drift was observed. All measuring equipment had been subject to laboratory calibration traceable to national standards within the previous 12 months, as shown in Table 9.1. The calibrator is subject to an annual laboratory calibration, the most recent having been on 09 October 2014 (refer to Appendix 9.8 for calibration certificates).

9.6.4 Wind data during the 2012 survey were obtained from a temporary meteorology mast installed for the purposes of the background noise survey. It recorded ten-minute means of the wind speed and wind direction on site by means of an anemometer and wind vane 10 m above ground level. The wind data were logged and time stamped relative to GMT, thus facilitating synchronisation with the background noise data. The later installation of a 50 m meteorology mast allowed long-term wind shear data to be used to adjust the 10 m wind speeds, in order to allow for site-specific wind shear as required by the IOA Good Practice Guide. Data from the same 50 m mast were later used to obtain the derived wind speeds at 10 m height during the 2015 background noise survey, using the methodology recommended in the IOA Good Practice Guide.

9.6.5 A tipping bucket type rain gauge with electronic logging device was installed at one of the noise measurement locations in each case: the garden of 6 Middlemuir Road (2012) and the yard of Westerhouse (2015). Rainfall data were also downloaded to a laptop at the end of each survey.

Measurement and Prediction Locations

9.6.6 Locations for the measurement of background noise levels in proximity to the Revised Development are shown in Table 9.2 and Appendix 9.1. These locations were selected to be representative of outdoor amenity areas of the closest residential properties facing the turbines. Photographs of the monitoring locations are provided at Appendix 9.2. The data logging sound level meters were placed as far as practicable at a minimum distance of 3.5 m from any reflective surface such as buildings and vertical walls, generally in areas which might be used for outdoor relaxation in warm weather, and away from sources of extraneous noise such as farm machinery, watercourses or wooded areas.

Table 9.2 – Noise Measurement Locations

No.	Location	Easting	Northing	Dates
N1	Westerhouse	282815	633495	3 July – 1 August 2012
N2	Station House	282082	630957	3 July – 1 August 2012
N3	6 Middlemuir Road	281014	634436	3 July – 1 August 2012
N1	Westerhouse	282822	633491	26 March – 27 April 2015

9.6.7 The locations at Westerhouse differed slightly on the two surveys because property in the yard had been moved in the intervening period, but the two locations were only 8 m apart and both were in

the yard behind (east of) the property. The rain gauge was also deployed in this area for the 2015 survey. There were no obvious sources of noise apart from occasional distant road traffic.

9.6.8 The location at Station Road was in the garden to the west of the property's south-western corner, on previously cultivated ground. The location is largely surrounded by open fields used for pasture. Occasional turbine noise was detected from the Hagshaw Hill Wind Farm to the west, but only when the wind direction was such that the turbines were upwind of the location.

9.6.9 The location at 6 Middlemuir Road was behind the single-storey dwelling on a paved area. It would have been preferable to locate the meter on the grassed area to the front (east) of the property, but satisfactory arrangements could not be made for the security of the instrument in that location. The rain gauge was also placed near this noise monitor for the entire duration of the 2012 survey.

9.6.10 Locations selected for the calculation of noise levels from the Revised Development are set out in Table 9.3 and shown in Appendix 9.1.

Results of Background Noise Surveys

9.6.11 The results of the automatic monitoring of noise and wind speed are presented graphically in the Appendices to this Chapter. Appendix 9.3 shows the noise level and wind speed histories. The ETSU-R-97 guidance does not provide a method for disregarding 'doubtful' data, but the IOA Good Practice Guide recommends a method for discarding data points which may possibly be affected by rainfall. Data regarded as doubtful because of rainfall or other extraneous noise is included in the time histories, but was discarded thereafter. It can be seen that the measured noise levels at all locations were dependant mainly on the wind speed.

9.6.12 The following method was used to reduce the time history data for each measurement location into a format for which the best practice method for determining background noise curves could be used.

- With the data in chronological order, a level versus time graph is plotted for each noise measurement location (a time history). A time history of the derived wind speed at 10 m height is also plotted on each.
- All normal daytime periods are removed (07:00h to 18:00h on weekdays, and 07:00h to 13:00h on Saturdays).
- The remaining data points are divided into two periods, 'night-time' being 23:00h to 07:00h daily, and 'daytime amenity periods' being all the remaining data.
- Points which were possibly affected by rainfall according to the rain gauge time history, and the preceding 'dry' data point before each registered bucket tip signifying rainfall (however slight) are removed.
- A graph is plotted for each location, for each period (daytime amenity or night-time), showing the background noise level against the derived ten-minute wind speed at 10 m height (an x-y plot).

9.6.13 Appendix 9.4 shows scatter plots for daytime amenity periods and night-time periods at each of the noise monitoring locations, with noise levels plotted against the adjusted wind speed, and doubtful data removed. The best-fit curve is superimposed on the data in each case in order to derive the typical wind-dependant background noise levels as recommended by ETSU-R-97 and the IOA Good Practice Guide.

9.6.14 The spread of wind directions occurring during the two background noise survey periods is shown in Appendix 9.5. The wind direction in July 2012 was mostly from the west or south-west, but with significant periods of easterly winds. In April 2015 the wind direction was mainly between westerly and southerly, with relatively little wind from the east or north. In both cases a wide range of wind speeds occurred, resulting in data sets which were fit for purpose.

9.6.15 ETSU-R-97 provides for the use of proxy locations where it is considered unnecessary or impractical to conduct background noise measurements at all potential noise receptors. The IOA Good Practice Guide says that when choosing a location that will serve as a proxy for others, the basis for selection

is that it can reasonably be claimed, from inspection and observation, to be representative of the non-surveyed locations, in line with the guidance on measurement site selection. No general guidance is offered on the number of measurement locations because this is necessarily site-specific. The scheme adopted for proxy locations for the Revised Development is shown in Table 9.3.

Table 9.3 – Noise Prediction and Proxy Background Noise Measurement Locations

Receptor	Name	Uses background curves from
R1	Westerhouse	N1 Westerhouse (2015)
R2	Station House	N2 Station House (2012)
R3	8 Middlemuir Road	N3 6 Middlemuir Road (2012)
R4	Craigend	N1 Westerhouse (2015)
R5	West Toun House	N1 Westerhouse (2015)
R6	Braehead	N3 6 Middlemuir Road (2012)
R7	Midfield Road	N3 6 Middlemuir Road (2012)
R8	Gardens House	N1 Westerhouse (2015)
R9	Scrogton	N2 Station House (2012)
R10	Braidlea	N2 Station House (2012)
R11	Scrogtonhead	N2 Station House (2012)
R12	Stockhill	N1 Westerhouse (2015)
R13	Gunsgreen	N3 6 Middlemuir Road (2012)

9.6.16 The consented noise limits, derived from the two background noise survey campaigns and expressed to the nearest whole decibel, are shown in Table 9.4. Different noise limits apply to daytime and night-time, and the limits are expressed against the derived integer wind speeds at 10 m height on site. The residents at Westerhouse and Station House have financial interests in the project and therefore qualify for the higher noise limits specified in ETSU-R-97.

9.6.17 All noise limits derived from the Westerhouse background measurements as a proxy location use the 2015 data set. The noise limits derived from background measurements at Station House are directionally filtered in line with IOA Good Practice Guide recommendations: data points for which the wind was in the western quadrant were discarded to remove any risk of corruption by noise from existing turbines to the west of the location. In the case of Station House (only) the limits will differ from those in the planning conditions because of the financial interest of that property in the Revised Development. The noise limits in Table 9.4 have been adjusted to account for this.

Table 9.4 – Noise Limits in existing Planning Conditions for the Consented Development (amended to reflect financial involvement of Westerhouse and Station House in the Revised Development)

Name	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	10m/s	11m/s	12m/s
Daytime (07:00h – 19:00h)									
Westerhouse	45	45	45	45	45	45	45	45	45
Station House	45	45	47	47	48	50	52	54	56

Name	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	10m/s	11m/s	12m/s
Craigend, West Toun House, Gardens House, Stockhill	40	40	40	40	40	40	41	41	41
Scrogton, Braidlea, Scrogtonhead	40	40	40	42	43	45	47	50	52
Middlemuir Road, Braehead, Midfield Road, Gunsgreen	40	40	40	40	41	43	45	47	48
Night-time (19:00h – 07:00h)									
Westerhouse, Station House	45	45	45	45	45	45	45	45	45
All other locations	43	43	43	43	43	43	43	43	43

9.7 Predictive Calculations

Characteristics of Wind Turbine Noise

9.7.1 Noise from turbines is typically made up of a reasonably steady, broad-band noise of aerodynamic origin, which depends on blade tip speed, and mechanical noise from within the nacelle. On older designs of turbine, there may be a tonal noise element from mechanical components within the nacelle. Modern large turbine designs emit noise primarily of aerodynamic origin, with very little mechanical noise being transmitted into the environment. In general, none of the noise emission is tonal in character. The broadband noise is amplitude modulated, i.e. it varies in amplitude as the three turbine blades rotate, with the maximum modulation occurring on the downward movement of each blade from roughly horizontal to near-vertical. This variation of the instantaneous sound level is accounted for in the noise prediction methodology.

Turbine Sound Power Data

9.7.2 It is intended to install turbines in the 3.6 – 3.8 MW class at the Revised Development site. The noise data used in the predictive calculations are those for the Siemens SWT-3.6-130 turbine in its normal operational mode (i.e. not noise-restricted), which is the current candidate turbine. The method used to obtain sound power data conformed to the IEC 61400-11 standard, the most commonly used procedure, which calls for measurements close enough to the turbine that background noise is insignificant. The data are derived from the manufacturer's published data (specification), so an uncertainty of 2dB was included in the sound power levels used for noise prediction purposes as required by the Institute of Acoustics guidance documents.

9.7.3 The turbines would be configured for a maximum overall sound power level (each turbine, manufacturer's reported test levels plus uncertainty) of 108dB (A) at the reference wind speed (v_{10}) of 8 m/s. The sound power depends on wind speed up to the maximum governed rotational speed of the turbine, and the closest approach of wind farm noise to the limit curve is almost invariably within the 6 to 8 m/s wind speed range. =Spectral information for the calculation of excess attenuation over distance, were also taken from the manufacturer's specification with an appropriate adjustment to ensure equivalence to the overall warranted level plus uncertainty.

Turbine Locations

9.7.4 The proposed turbine coordinates are shown in Table 9.5.

Table 9.5 – Turbine Coordinates for Noise Predictions

Turbine No.	Easting	Northing	Turbine No.	Easting	Northing
T1	280331	633205	T8	282070	632421
T2	280690	633124	T9	282430	632168
T3	281111	633045	T10	282119	631854
T4	281579	633144	T11	281771	631965
T5	281788	632753	T12	281398	631680
T6	282274	632926	T13	281579	631486
T7	282570	632685			

Calculation Procedure for Wind Turbine Noise

9.7.5 The method adopted for the prediction of noise from the turbines is the ISO 9613-2:1996 method interpreted in the light of the IOA Good Practice Guide. The model assumes sound radiation from a point source with only slight attenuation by ground effects. The attenuation resulting from ground effects and atmospheric absorption varies with frequency and distance, and the predictions are carried out in octave bands with the overall A-weighted levels being calculated from the results. The source sound power levels used for calculation purposes take no account of the available noise reduction methods on the candidate turbine or similar types, although various modifications may be available.

9.7.6 The IOA Good Practice Guide states that in order to give reliable predictions of the aggregate noise levels at receptor locations, certain assumptions should be made. These represent the worst case for noise immission of each receiver, i.e. for the condition when the wind blows from the turbines to the receptor. The assumptions are:

- all turbines are directly upwind of the receptor;
- the manufacturer's warranted noise data, or published test data, plus an allowance for uncertainty, are used as input to the acoustical model;
- a ground attenuation factor G = 0.5 for G_s, G_m and G_r (the ground types in the source region, middle region and receiver region as defined by ISO 9613-2);
- the noise source of each turbine is concentrated at turbine hub height;
- a receptor height of 4 m, corresponding to a first-floor window (note that this conflicts with ETSU-R-97 recommendations).

9.7.7 In order to calculate the steady noise from the proposed wind turbines the effect of each turbine at each receptor location is calculated. ETSU-R-97 suggests that the steady nature of the noise emitted by wind turbines is such that the level difference between L_{Aeq} and L_{A90} is typically 2dB, and this has been confirmed by readings from several turbines in various types of terrain; the approach is advocated by the IOA Good Practice Guide. A 2dB deduction was therefore made from the overall sound power level to yield the typical L_{A90} for calculation purposes. The direction of the wind makes the noise from the turbine effectively directional, since the noise level at a given distance upwind of the turbine will be considerably lower than at the same distance downwind.

9.7.8 The IOA Good Practice Guide also provides guidance on the screening effects of barriers to the propagation of sound, and the effects of the landform between turbine and receptor. A wireframe visualisation of the proposed turbines viewed from each of the receptor locations was reviewed,

and where no part of a turbine will be visible, a deduction of 2dB was made from the contribution of that turbine to allow for screening by the landform. In many cases the reduction in noise contribution may be considerably greater, but for robustness only 2dB was deducted.

9.7.9 The OS grid coordinates of the noise prediction locations are shown in Table 9.6. The coordinates were selected to represent the nearest point to any turbine within the curtilage of the property named, with the exception of R13 Gunsgreen. This is a location in the centre of an area for which Planning Permission in Principle has been granted for a housing development, although no houses have yet been built and the disposition of the buildings on site, house types etc is not known.

Table 9.6 –Coordinates for Noise Prediction Locations

Receptor	Easting	Northing	Receptor	Easting	Northing
R1 Westerhouse	282803	633471	R8 Gardens House	283990	632358
R2 Station House	282083	630975	R9 Scrogton	282644	630470
R3 8 Middlemuir Road	281014	634402	R10 Braidlea	282943	631012
R4 Craigend	282805	633537	R11 Scrogtonhead	282275	630245
R5 West Toun House	282860	633779	R12 Stockhill	278470	634124
R6 Braehead	281196	634407	R13 Gunsgreen	280950	634100
R7 Midfield Road	281486	634486			

Results of Noise Predictions

9.7.10 The predicted worst-case noise levels for the receptor locations from the Revised Development are presented graphically in Appendix 9.6. The curves shown represent the assumed prevailing background noise characteristic, the aggregate turbine noise and the assumed daytime or night-time noise limit curves applied at each location as appropriate. The results are also shown to the nearest whole decibel in Table 9.7. The amount by which the wind farm complies with the assumed noise limits are presented in Table 9.9.

Table 9.7 – Predicted Worst-Case Noise Immission Levels dB $L_{A90,10min}$ Against 10 m Wind Speed

Receptor	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	10m/s	11m/s	12m/s
Westerhouse	27	33	36	36	36	36	36	36	36
Station House	28	33	36	37	37	37	37	37	37
8 Middlemuir Road	22	27	31	31	31	31	31	31	31
Craigend	27	32	35	36	36	36	36	36	36
West Toun House	25	30	33	34	34	34	34	34	34
Braehead	22	27	31	31	31	31	31	31	31
Midfield Road	21	27	30	30	30	30	30	30	30
Gardens House	20	25	29	29	29	29	29	29	29
Scrogton	22	27	30	31	31	31	31	31	31
Braidlea	24	29	32	33	33	33	33	33	33
Scrogtonhead	21	27	30	30	30	30	30	30	30
Stockhill	16	21	25	25	25	25	25	25	25

Receptor	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	10m/s	11m/s	12m/s
Gunsgreen	24	30	33	33	33	33	33	33	33

9.8 Assessment of Potential Effects

9.8.1 All receptor locations are assumed to be noise-sensitive, although properties occupied by persons with a financial interest in the project are deemed slightly less sensitive: this subjective reaction is anticipated by ETSU-R-97 which considers that higher noise limits are appropriate for such locations.

9.8.2 The magnitude of change in noise levels depends on the degree to which sounds from the turbines exceed the prevailing background sound level, and thus on how audible the sound may be under different wind conditions.

Construction

9.8.3 During the construction of the turbines there will inevitably be additional road traffic in the vicinity of the site, but vehicle routes will be carefully prescribed in consultation with SLC, in order to minimise disruption and disturbance. The frequency and numbers of such vehicle movements will be insufficient to affect the road traffic noise experienced by local residents, and site access will be gained directly from the national motorway network: there will be no significant effects on the local road network in residential areas. The permitted hours for deliveries and for working hours on site are limited by planning condition for the Consented Development and it is considered that this remains appropriate for the Revised Development.

9.8.4 Detailed ground investigations will be undertaken at a later stage of project development, prior to construction. Piled foundations are not anticipated, and conventional gravity foundations will be used. The installation process involves ground excavation, placement of steel reinforcement, and concrete pouring. The process is relatively quiet, with the typical 360^{o} excavator emitting a maximum noise level of around 85dB(A) at a distance of 5 m. There will also be on site, from time to time, tipper lorries to deliver stone for tracks and remove spoil, and concrete mixers to deliver materials. Each of these events will be short-lived, and the noise levels emitted by the machinery will be comparable with those for an agricultural tractor. Since the operations will be restricted to the normal working day, and because of the separation distances between turbines and local noise-sensitive locations, no significant noise will be received at residential properties.

9.8.5 The effects of distance, ground effects and air absorption mean that the resulting noise levels at the nearest residential property will be a maximum of 40dB L_{Aeq}, the minimum separation distance being around 750m Operations at an individual turbine foundation would take no more than a day or two, but even in a flat calm the resulting noise would only slightly exceed the daytime background noise level.

9.8.6 The construction of access tracks will be limited to local ground levelling operations, movement of road stone or gravel by tipper lorry, and compaction of the tracks using rollers. The maximum noise levels from the machinery used will be of the order of 80dB(A) at 5m distance, and although the activities may be audible from time to time at the closest noise receptor locations, they will not be intrusive. The noise from construction is low in magnitude of change and is **not significant**.

9.8.7 Vibration from construction operations, whether at wind turbine locations or near site access tracks, will be undetectable beyond a few ten of metres from the vibration source. The vibration impact from the construction operations is **not significant**.

9.8.8 The vibration arising as a result of the passage or operation of an item of construction machinery, including rock processing and handling machinery, will be such that no ground vibration during construction or rock winning operations will be detectable to a human observer inside neighbouring properties. The levels of vibration inside these properties will be several orders of magnitude lower than the architectural damage criteria given in BS.7385-2:1993, and at least two orders of

magnitude below the levels perceptible to a human observer. This magnitude of change is negligible, and **not significant**.

Operation

Table 9.9 – Predicted Margins of Compliance with Consented Noise Limits, dB

Receptor	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	10m/s	11m/s	12m/s
Daytime									
Westerhouse	18	12	9	9	9	9	9	9	9
Station House	17	12	11	10	11	13	15	17	19
8 Middlemuir Road	18	13	9	9	10	12	14	16	17
Craigend	13	8	5	4	4	4	5	5	5
West Toun House	15	10	7	6	6	6	7	7	7
Braehead	18	13	9	9	10	12	14	16	17
Midfield Road	19	13	10	10	11	13	15	17	18
Gardens House	20	15	11	11	11	11	12	12	12
Scrogton	18	13	10	11	12	14	16	19	21
Braidlea	16	11	8	9	10	12	14	17	19
Scrogtonhead	19	13	10	12	13	15	17	20	22
Stockhill	24	19	15	15	15	15	16	16	16
Gunsgreen	16	10	7	7	8	10	12	14	15
Night-time									
Westerhouse	18	12	9	9	9	9	9	9	9
Station House	17	12	9	8	8	8	8	8	8
8 Middlemuir Road	21	16	12	12	12	12	12	12	12
Craigend	16	11	8	7	7	7	7	7	7
West Toun House	18	13	10	9	9	9	9	9	9
Braehead	21	16	12	12	12	12	12	12	12
Midfield Road	22	16	13	13	13	13	13	13	13
Gardens House	23	18	14	14	14	14	14	14	14
Scrogton	23	18	15	14	14	14	14	14	14
Braidlea	21	16	13	12	12	12	12	12	12
Scrogtonhead	24	18	15	15	15	15	15	15	15
Stockhill	27	22	18	18	18	18	18	18	18
Gunsgreen	19	13	10	10	10	10	10	10	10

9.8.9 The noise immission levels from the 13 turbines will fall within the consented noise limits derived according to ETSU-R-97 and the IOA Good Practice Guide. It follows that the magnitude of change is slight, and the effect of noise from the proposed wind turbines on local receptors is **not significant**.

9.8.10 Ground-borne vibration from wind turbines is neither discernible by a human observer, nor measurable under normal circumstances, at distances greater than a few tens of metres from the turbine. The magnitude of change in vibration is therefore negligible, and the significance of effect is therefore **none**.

9.8.11 ***Decommissioning***

9.8.12 The noise impact during decommissioning and removal of the turbines will be no greater or more significant than that during construction.

Requirements for Mitigation

9.8.13 Although no noise mitigation measures are indicated to be necessary, it is possible to mitigate the noise impact of a turbine or turbines under certain operating conditions depending on the type of turbine and the options offered by the manufacturer. Particular wind speeds with the wind blowing from a particular sector will give rise to 'worst case' noise impacts, and under such conditions it will be possible to reduce the noise emissions from individual turbines under software control. These mitigation measures do not need to be specified in advance of turbine construction and can be implemented and adjusted as necessary in order to meet noise limits imposed by planning conditions.

9.8.14 The need for operational mitigation measures will be established as part of the post-construction commissioning process, and will involve noise limit compliance measurements.

9.8.15 Noise mitigation during the construction phase of the turbines and infrastructure will be accomplished by limiting the permitted hours of work, and of deliveries to site by HGV (abnormal loads excepted). The Consented hours of 07:00h to 19:00h weekdays, and 07:00h to 13:00h on Saturdays, with no audible works at any other time, are appropriate.

Assessment of Residual Effect Significance

9.8.16 Following implementation of mitigation measures, the construction noise effects on noise-sensitive receptors are assessed as **not significant**. Operational noise effect of the proposed wind turbines is assessed as **not significant**.

Limitations to Assessment

9.8.17 The assessment is based on best practice guidelines at the time of writing and the worst-case scenario was modelled. There may be variations in the instantaneous sound levels from turbines which mean that they may be heard from time to time by a casual observer.

9.9 Cumulative Assessment

Methodology

9.9.1 There are several operational and consented wind farms within approximately 5 km of the Revised Development. Those considered of relevance to the cumulative noise assessment are Hagshaw Hill and its Extension scheme consisting of 46 turbines, Dalquhandy (15 turbines), Nutberry (6 turbines), Galawhistle (21 turbines), Poniel (3 turbines), Hazelside (2 turbines) and Cumberhead (11 turbines). The locations of the turbines are shown in Figure 3.4.

9.9.2 For initial screening purposes, all turbines in the projects listed above, as well as the thirteen turbines within the Revised Development, were regarded as a single development using various different turbine types as appropriate, and the ISO9613-2 noise prediction methodology was applied on the basis that all turbines are approximately upwind of each receptor in turn. If this approach identified any potential cumulative noise issues then a more detailed assessment could be made, taking into account wind direction.

9.9.3 There will be considerable screening of turbines by the landform, particularly for distant turbines. The IOA Good Practice Guide states that under these circumstances it is acceptable, and robust, to deduct 2dB overall from the contribution of any individual turbine that is not partially or wholly

visible from the receiver location. These deductions were made with reference to the wireline visualisations.

9.9.4 The results of the cumulative noise predictions at the thirteen receptor locations used for the assessment, with every relevant turbine within a radius of 5 km of the proposed turbines being included, are shown to the nearest whole decibel in Appendix 9.7 Table 9.7.1. These results are compared with the proposed noise limits for the Revised Development in Appendix 9.7 Table 9.7.2. This can be considered a broad-brush approach to the recommendations of the IOA Good Practice Guide, and includes 2dB of screening for any turbine not visible from the location in question. No allowance is made for directivity, and every turbine was treated as if it were directly upwind of the receptor at a single point in time, which in reality would never be the case.

Results and Commentary, Cumulative Noise Levels

9.9.5 This broad-brush approach exaggerates the cumulative noise effects, because as can be seen from the schematic map in Appendix 9.1 (9.1.3 Map), there are no receptor locations that can ever simultaneously fall downwind of every wind farm in the locality. Nevertheless, the proposed noise limits for the Revised Development can be met under these exaggerated conditions at all but three of the receptor locations used in the present study, by all turbines listed in paragraph 9.9.1 and the Revised Development turbines, with the exceptions being Craigend, Stockhill and the consented housing development at Gunsgreen.

9.9.6 The apparent minor cumulative excess at Craigend necessitated further examination, taking into account the directional effects of all wind turbines in order to arrive at a better estimate of the cumulative noise effects. This is described below.

9.9.7 The location at Craigend places the dwelling approximately midway between the thirteen Revised Development turbines and the three at Poniel. This means that the worst case wind direction for the Revised Development puts the three Poniel turbines directly downwind, and their effects on the cumulative noise immission levels are therefore exaggerated. The contribution from each of the three Poniel turbines will be reduced by between 10 and 13 dB overall at Craigend, and there will be no actual increase in noise from the introduction of the Revised Development turbines. The magnitude of the noise impact will therefore be slight, and the noise effect is therefore **not significant**.

9.9.8 At Stockhill, the additive effect of the Revised Development turbines on the noise already occurring in the worst case from currently operational and consented turbines (excluding Cumberhead) is only 0.1dB, which will be completely undetectable. Stockhill Farm is a financially interested party in the Cumberhead Wind Farm and a higher noise limit (minimum 45dB) is applicable to those turbines. Any excess over this higher limit will be the responsibility of the operator of that project. The noise effect is therefore **not significant**.

9.9.9 The predicted exceedance at the permitted housing at Gunsgreen using the broad-brush approach in Appendix 9.7 was very slight. The layout of proposed dwellings at Gunsgreen is not yet known, but acoustical screening within the housing estate will tend to reduce the levels, which are already influenced by the permitted Dalquhandy Wind Farm. The noise effect is therefore considered to be **not significant**.

9.10 Summary

9.10.1 Baseline noise surveys were undertaken in order to establish the pre-existing sound levels at selected local dwellings. These were used together with concurrent wind speed measurements on the site of the Revised Development to establish noise limits for the wind turbines in accordance with best practice guidance. This assessment has concluded that the limits previously included in the planning conditions for the Consented Development (CL/15/0273) will be equally appropriate for, and can be complied with by, the Revised Development consisting of 13 wind turbines. It should, however be noted that the properties at Westerhouse and Station House are financially involved in the Revised Development and the applicable noise limits should therefore reflect this, as set out in Table 9.4. Permission is therefore sought to amend condition 45 of the Consented Development (ref. CL/15/0273) accordingly. The noise immission levels at local noise-sensitive locations were

calculated using internationally recognised prediction methods and the robust results were then compared with the proposed noise limits. The design of the wind farm was found to be capable of meeting these limits. Its effect on the noise environment experienced by local resident is therefore **not significant**.

9.10.2 The cumulative effects of the Revised Development and all relevant operational and consented wind turbines within 5 km of the proposed turbines were calculated in the same way. The methodology was expected to over-predict the cumulative noise immission levels and the excesses (if any) over the proposed noise limits were slight. The increase in noise from the Revised Development turbines over that already occurring or likely to occur from operational and consented wind farms will be subjectively unnoticeable at most locations, and within acceptable limits. The effect is therefore **not significant**.

Table 9.10 – Summary Table

Description of Effect	Significance of Potential Effect		Mitigation Measure	Significance of Residual Effect		Comparison with the Consented Development
	Significance	Beneficial/ Adverse		Significance	Beneficial/ Adverse	
Construction noise	Not Significant	Adverse	Control of working hours and best working practices	Not Significant	Adverse	No Change
Operational noise	Not Significant	Adverse	Operational monitoring to ensure compliance, with the option of selective constraint of turbine operation if found to be a requirement.	Not Significant	Adverse	No Change

9.11 References

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