Tangy IV Wind Farm Section 36C Variation

Technical Appendix 11.1: Baseline Noise Data Reanalysis

Tangy IV Wind Farm - Data Reanalysis.
Argyll and Bute.
SSE Renewables Services (UK).

ACOUSTICS
TANGY IV - DATA REANALYSIS

REVISION 2 – 25 MARCH 2026

Audit sheet.

Rev.	Date	Description of change / purpose of issue	Prepared	Reviewed	Authorised
1	10/02/2026	First version	SG	MMC	MMC
2	25/03/2026	Minor update	SG	MMC	MMC

Project number: 791-0432945
Document reference: 791-432945-HLE-RP-AC-Tangy IV Data Reanalysis-Rev2.docx

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1. Introduction

1.1.1 A background noise survey was previously undertaken in 2013 as part of the Tangy III Wind Farm assessment, and the same data was reference in the analysis of noise impact from the Tangy IV Wind Farm and referenced to a hub height of 90 m which was representative of the turbines proposed then[1]. In this current report, this background noise data has been reanalysed to represent a revised hub height of 125 m. The report also sets out all details of the measurements and how the data has been reanalysed.

1.1.2 A glossary of noise terms is provided in Annex A.

2. Baseline

2.1 General Description

2.1.1 The noise environment in the surrounding area is generally characterised by sources such as wind disturbed vegetation, birds, farm animals and to the west of the site, coastal water movement. Other sources of noise include intermittent local road and agricultural vehicle movements in the area.

2.2 Details of the Baseline Background Noise Survey

2.2.1 A total of four noise monitoring locations were previously agreed with the local authority (Argyll and Bute Council) as being representative of the background noise environment in the vicinity of the Proposed Development. Specifically, at the time of the survey, the existing Tangy I and Tangy II turbines were operational and, as such, it was not possible to obtain measurements in the vicinity of the existing site without these measurements being influenced to some degree by noise form the existing turbines. This would have been contrary to the requirements of ETSU-R-97[2] and the Institute of Acoustics Good Practice Guide (IOA GPG)[3]. As such, proxy locations were discussed and agreed that are far enough from the existing turbines so as not to be affected by noise from Tangy I and Tangy II, but which can be considered representative of baseline noise levels in the vicinity of the proposed development. The four locations are shown on the plan in Annex B and listed in Table 1.

Table 1 - Background Noise Monitoring Locations (approximate Easting/Northing)

No.	Property	Easting	Northing
1	Killocraw	166031	630687
2	Drum Farm	167140	625475
3	Gobagrennan	170591	628598
4	Corrylach	170526	630384

2.2.2 These baseline surveys were undertaken in 2013 but, in the absence of significant changes to the noise environment in the area since then, would remain representative of background noise levels in the area.

2.2.3 The equipment used for the survey comprised four Rion NL 31 / NL-32 logging sound level meters. All sound level meters were calibrated in a laboratory in accordance with accepted requirements as set out in the IOA GPG, with details provided in Annex C, and certificates available on request. All

[1] See Hoare Lea Report reference REP-1004960-MMC-20180806-Tangy IV-NIA-2 dated August 2018, included as Technical Appendix 14.1 of the EIA report for the Tangy IV Wind Farm.

[2] ETSU R 97, the Assessment and Rating of Noise from Wind Farms, Final ETSU-R-97 Report for the Department of Trade & Industry. The Working Group on Noise from Wind Turbines, 1997.

[3] A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.

meters were enclosed in environmental cases with battery power to enable 21 days continuous logging at the required ten-minute averaging periods. Outdoor windshield systems were used to reduce wind induced noise on the microphones and provide protection from rain. These windshield systems were supplied by the sound level meter manufacturer and maintain the required performance of the whole measurement system when fitted. The environmental enclosures provided an installed microphone height of approximately 1.2 to 1.5 metres above ground level, consistent with the requirements of ETSU-R-97.

2.2.4 The sound level meters were located on the wind farm side of the property in question where possible, never closer than 3.5 metres from the façade of the property and as far away as was practical from obvious atypical localised sources of noise such as running water, trees or boiler flues. Details and photographs of the measurement locations are presented in Annex C.

2.2.5 All measurement systems were field-calibrated on their deployment on 13th September 2013 and upon collection of the equipment on the 6th October 2013 (except for the meter at Gobagrennan that was deployed and field-calibrated on the 13th September, field-calibrated on the 6th October and field-calibrated and collected on the 5th November 2013 due to an extension to the monitoring period at this location that was necessary owing to a battery failure). No acoustically important (>0.5 dB(A)) drifts in calibration were found to have occurred on any of the systems. This equates to a total ETSU-R-97 analysis period of at least 20 days at Killocraw, Drum Farm and Corrylach and 14 days at Gobagrennan. The total survey period is in excess of the minimum of one week required by ETSU-R-97, and a suitably representative range of wind conditions was obtained in line with IOA GPG requirements.

2.2.6 All measurement systems were set to log the $L_{A90,10min}$ and $L_{Aeq,10min}$ noise levels continuously over the deployment period. The internal clocks on the sound level meters were all synchronized with Greenwich Mean Time (GMT) by the use of a Global Positioning System (GPS) receiver. The clock on the meteorological mast from which wind data was collected was also set to GMT.

2.3 Measured Background Noise Levels

2.3.1 The ETSU-R-97 assessment method requires noise data to be related to wind speed data at a standardised height of ten metres, with wind speeds either directly measured at a height of ten metres or by calculation from measurement at other heights, the appropriate choice being determined by practitioner judgement and the available data sources. Since the publication of ETSU-R-97, the change in wind speed with increasing height above ground level has been identified as a potential source of variability when carrying out wind farm noise assessments. The effect of site specific wind shear can be appropriately addressed by implementing the ETSU-R-97 option of deriving ten metre height reference data from measurements made at taller heights. It is this method that has been used in the noise assessment for the proposed development to account for the potential effect of site specific wind shear. This method is consistent with the preferred method described in the IOA GPG. Wind speeds were measured on an 80 metre high meteorological mast located within the boundary of the proposed development site. Values of wind speed at a standardised height of ten metres were calculated from those measured on the mast (to obtain a "standardised wind speed").

2.3.2 This analysis was updated in the present assessment to account for potential hub heights of 125 m, which is higher than the 90 m previously assumed in the analysis for the Tangy IV Wind Farm. Full details of the calculation method are given in Annex F. This remains in line with the guidance of the IOA GPG as the tallest height used (80 m) is more than 60% of the assumed hub height of 125 m.

2.3.3 Figures D1 to D4 in Annex D show the range of wind conditions experienced during the noise survey period. During the quiet daytime and night-time periods wind speeds were typically less than 18 m/s. The wind was observed to be directed most frequently from the northwest during the survey period, with a wind direction from the southeast also being common. It is understood that this is generally in line with the long-term wind rose for the site.

2.3.4 Figure E1 to E8 in Annex E show the results of the background noise measurements at each of the four monitoring locations. The background noise data are presented in terms of $L_{A90,10min}$ background noise levels plotted as a function of the standardised ten metre wind speed. Two plots are shown for each location, one for quiet daytime periods and the other for night-time periods, both derived in accordance with ETSU-R-97.

2.3.5 Data from all survey locations were inspected to identify periods which may have been influenced by extraneous noise sources, giving rise to atypical and elevated levels. ETSU-R-97 suggests that any data that may have been affected by rainfall be excluded from the analysis. The meteorological monitoring system had a rain gauge installed during the noise survey period; data from this gauge were therefore used to exclude those periods where rain was indicated.

2.3.6 In addition to the impact noise of rainfall on surrounding vegetation and the sound level meter itself, in some environments rainfall can result in appreciable changes in background sound levels, for example as a result of wet roads which increase tyre noise emissions or dissipating flow noise in water courses and drainage systems. Observations whilst on site indicated traffic noise to be a negligible influence on background sound levels, and thus the possible effect of increased tyre noise from wet roads is not considered relevant to this site.

2.3.7 In terms of water flow noise, some locations around the site (and in particular Corrylach and Gobagrennan) have burns that run in relatively close proximity to the property. In these instances, the noise monitoring equipment was located as far as reasonably practical from water courses. Water flow noise in water courses was evident in some of the measurements obtained, characterised by relatively high noise levels after periods of rain followed by a gradual reduction in noise levels, and the measured data has been filtered to remove these periods.

2.3.8 Notwithstanding this, the possibility exists that some of the measured background noise data at low wind speeds may have been increased by other extraneous or rain-related influences. Time histories of the noise levels at each survey location were inspected to look for any atypical relationships when compared to the wind speeds present during that time. Any elevated levels found in this way were excluded. The trend of the data when plotted against wind speed was also inspected to look for atypical relationships or outliers within the dataset which were excluded. A variation in background noise levels with wind direction was observed at some of the monitoring locations, and in particular at Killocraw due to the relatively exposed character of the location in westerly winds (see Annex C for details). For these properties, data was excluded for wind directions under which background noise levels were elevated. Any data removed from the analysis is indicated on the charts as red circles.

2.3.9 This is similar to the data analysis and exclusion previously presented as a basis for the assessment of the Tangy IV Wind Farm.

3. Results

3.1.1 Following removal of excluded data points, best fit lines were generated using a polynomial fit of a maximum of 3rd order, as considered appropriate in each case. The resulting background noise levels, derived in accordance with ETSU-R-97 for the 125 m hub height, are set out in Table 2 and Table 3.

Table 2 - Daytime Background Noise Levels (L_{A90}, dB) Derived from the Baseline Noise Survey According to ETSU-R-97

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Killocraw	25.6	26.1	26.8	27.8	29.0	30.5	32.1	34.1	36.3	38.7
Drum Farm	28.6	30.1	31.5	33.1	34.7	36.4	38.1	39.9	41.8	43.7
Gobagrennan	23.1	24.3	25.8	27.5	29.4	31.5	33.7	35.9	38.1	40.1
Corrylach	28.0*	28.0	28.6	29.9	31.8	34.0	36.5	39.0	41.3	43.5

* The polynomial line of best bit (see Figure E7) indicates a marginally higher background at 3 m/s than at 4 m/s, however this increase was disregarded in line with good practice.

Table 3 - Night-time Background Noise Levels (L_{A90}, dB) Derived from the Baseline Noise Survey According to ETSU-R-97

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Killocraw	24.6	25.8	27.0	28.2	29.4	30.6	31.8	33.1	34.3	35.5
Drum Farm	27.2	28.2	29.4	30.8	32.4	34.3	36.4	38.6	41.1	43.8
Gobagrennan	23.4	24.2	25.4	26.8	28.5	30.2	32.1	34.0	35.8	37.6
Corrylach	26.6	27.0	27.7	28.9	30.6	32.7	35.2	38.2	41.6	45.4

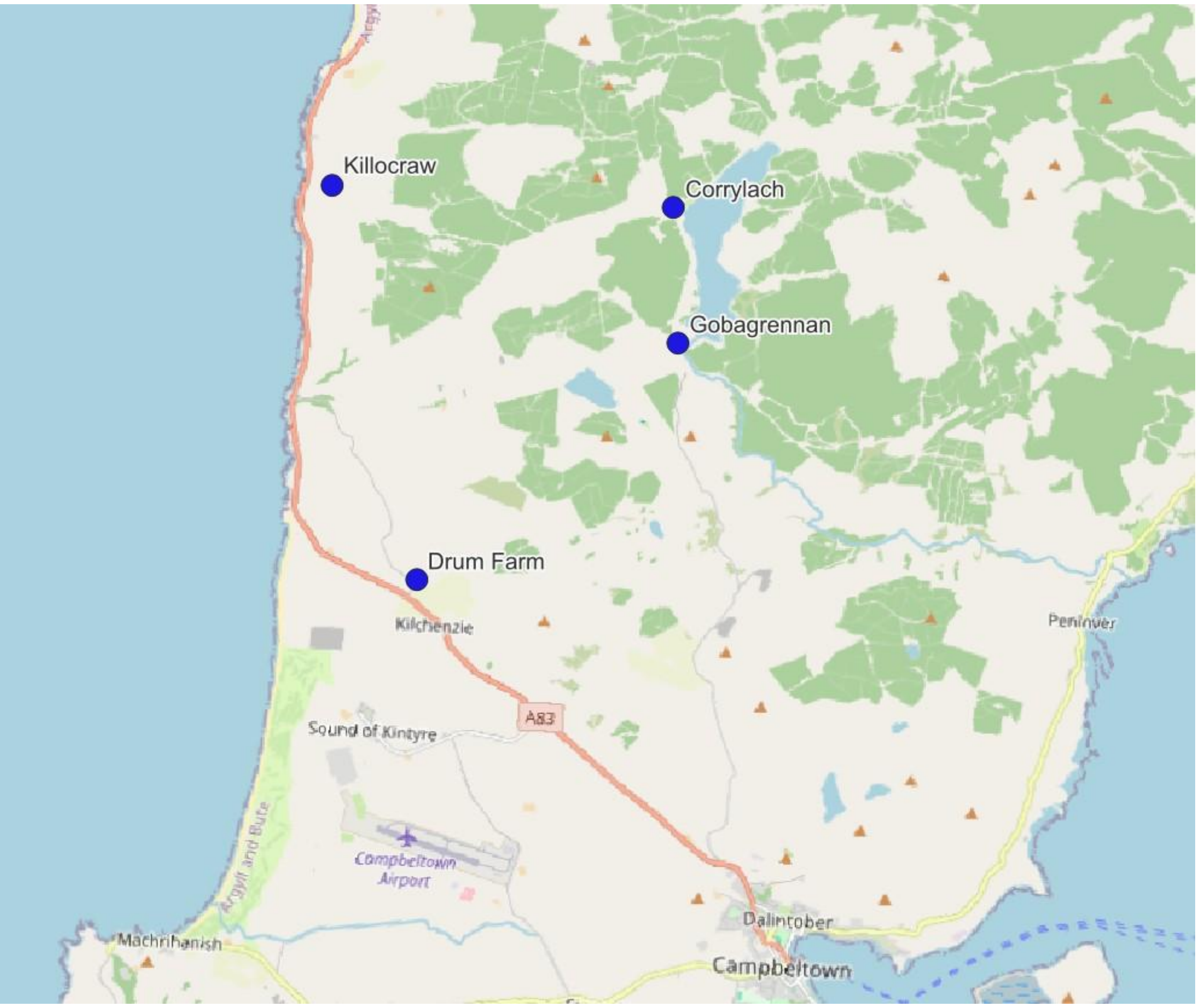
Annex A - Glossary of Acoustics Terminology

Terminology	Description
A-weighting	A filter that down-weights low frequency and high frequency sound to better represent the frequency response of the human ear when assessing the likely effects of noise on humans
Acoustic character	One or more distinctive features of a sound (e.g. Tones, whines, whistles, impulses) that set it apart from the background noise against which it is being judged, possibly leading to a greater subjective effect than the level of the sound alone might suggest
Acoustic screening	The presence of a solid barrier (natural landform or manmade) between a source of sound and a receiver that interrupts the direct line of sight between the two, thus reducing the sound level at the receiver compared to that in the absence of the barrier
Ambient noise	All-encompassing noise associated with a given environment, usually a composite of sounds from many sources both far and near, often with no particular sound being dominant
Annoyance	A feeling of displeasure in this case evoked by noise
Attenuation	The reduction in level of a sound between the source and a receiver due to any combination of effects including: distance, atmospheric absorption, acoustic screening, the presence of a building façade, etc.
Audio frequency	Any frequency of a sound wave that lies within the frequency limits of audibility of a healthy human ear, generally accepted as being from 20 Hz To 20,000 Hz
Background noise	The noise level rarely fallen below in any given location over any given time period, often classed according to daytime, evening or night-time periods (for the majority of the population of the UK the lower limiting noise level is usually controlled by noise emanating from distant road, rail or air traffic)
Db	Abbreviation for 'decibel'
Db(a)	Abbreviation for the decibel level of a sound that has been a-weighted
Decibel	The unit normally employed to measure the magnitude of sound
Directivity	The property of a sound source that causes more sound to be radiated in one direction than another
Equivalent continuous sound pressure level	The steady sound level which has the same energy as a time varying sound signal when averaged over the same time interval, t, denoted by $L_{Aeq,t}$
External noise level	The noise level, in decibels, measured outside a building
Filter	A device for separating components of an acoustic signal on the basis of their frequencies
Frequency	The number of acoustic pressure fluctuations per second occurring about the atmospheric mean pressure (also known as the 'pitch' of a sound)
Frequency analysis	The analysis of a sound into its frequency components
Ground effects	The modification of sound at a receiver location due to the interaction of the sound wave with the ground along its propagation path from source to receiver
Hertz	The unit normally employed to measure the frequency of a sound, equal to cycles per second of acoustic pressure fluctuations about the atmospheric mean pressure
Impulsive sound	A sound having all its energy concentrated in a very short time period
Instantaneous sound pressure	At a given point in space and at a given instant in time, the difference between the instantaneous pressure and the mean atmospheric pressure
Internal noise level	The noise level, in decibels, measured inside a building
L_{Aeq}	The abbreviation of the a-weighted equivalent continuous sound pressure level
L_{A10}	The abbreviation of the 10 percentile noise indicator, often used for the measurement of road traffic noise
L_{A90}	The abbreviation of the 90 percentile noise indicator, often used for the measurement of background noise
Level	The general term used to describe a sound once it has been converted into decibels
Loudness	The attribute of human auditory response in which sound may be ordered on a subjective scale that typically extends from barely audible to painfully loud

Terminology	Description
Noise	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure.
	Subjectively: sound that evokes a feeling of displeasure in the environment in which it is heard, and is therefore unwelcomed by the receiver
Noise emission	The noise emitted by a source of sound
Noise immission	The noise to which a receiver is exposed
Noise nuisance	An unlawful interference with a person's use or enjoyment of land, or of some right over, or in connection with it
Octave band frequency analysis	A frequency analysis using a filter that is an octave wide (the upper limit of the filter's frequency band is exactly twice that of its lower frequency limit)
Percentile exceeded sound level	The noise level exceeded for n% of the time over a given time period, t, denoted by $L_{An,t}$
Receiver	A person or property exposed to the noise being considered
Residual noise	The ambient noise that remains in the absence of the specific noise whose effects are being assessed
Sound	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure
	Subjectively: the sensation of hearing excited by the acoustic oscillations described above (see also 'noise')
Sound level meter	An instrument for measuring sound pressure level
Sound pressure amplitude	The root mean square of the amplitude of the acoustic pressure fluctuations in a sound wave around the atmospheric mean pressure, usually measured in pascals (Pa)
Sound pressure level	A measure of the sound pressure at a point, in decibels
Sound power level	The total sound power radiated by a source, in decibels
Spectrum	A description of the amplitude of a sound as a function of frequency
Standardised wind speed	Values of wind speed at hub height corrected to a standardised height of ten metres using the same procedure as used in wind turbine emission testing
Threshold of hearing	The lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa)
Tone	The concentration of acoustic energy into a very narrow frequency range

Annex B – Map of Noise Measurement Locations

Figure B1 Map showing the noise monitoring locations (blue dots)



Map data from OpenStreetMap

Annex C – Noise Monitoring Information Sheets

Table C1- Information on the measurement location, equipment and noise data at Killocraw.

Measurement Location	Killocraw
Measurement Location Description	Two residential properties next to a working farm. This monitoring location was selected as being representative of residential properties along the coast, whilst being far enough away from the existing Tangy wind farm not to be affected by noise from the existing operational turbines. The monitoring equipment was situated in the garden area of the residential properties, to the west of the building. This location was selected as being representative of the external amenity areas associated with the residential properties and was more than 3.5m from acoustically reflective surfaces such as the buildings. In addition, the residential buildings are located between the monitoring location and the farm, thereby providing a degree of screening from farm activities. The meter was located on the edge of the lawn, adjacent to some small shrubs. There are two mature trees in the garden area, which were at a distance of approximately 5 m from the monitoring location. The A83 runs at a distance of approximately 100 m to the west of this property, with the coast at a distance of approximately 150 m to the west of the property. Livestock were also noted in the fields in the vicinity of the property. Noise sources that were audible at this location during installation and collection of the equipment included the breeze in the trees, occasional road traffic on the A83, coastal water movement, livestock and birdsong. SLM Location: 166031, 630687.

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-31	00110060	31/01/2012
Pre-amplifier	Rion NH-21	07772	31/01/2012
Microphone	Rion UC-53A	307276	31/01/2012
Calibrator	B&K 4231	3000377	21/12/2012
SLM Range	20 – 110 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
1	13/09/2013 10:20	06/10/2013 06:30	94.0	93.7	-0.3	No significant drift

Data Exclusions
Data was excluded from this location during periods of rainfall and for wind directions within the sector between 170 and 360 degrees, as it was noted that measured baseline noise levels were significantly higher at this location when winds were from the west.

Figure C1 View of the monitoring location at Killocraw looking southeast

Figure C2 View of the monitoring location at Killocraw looking northwest

Figure C3 View of the monitoring location at Killocraw looking west

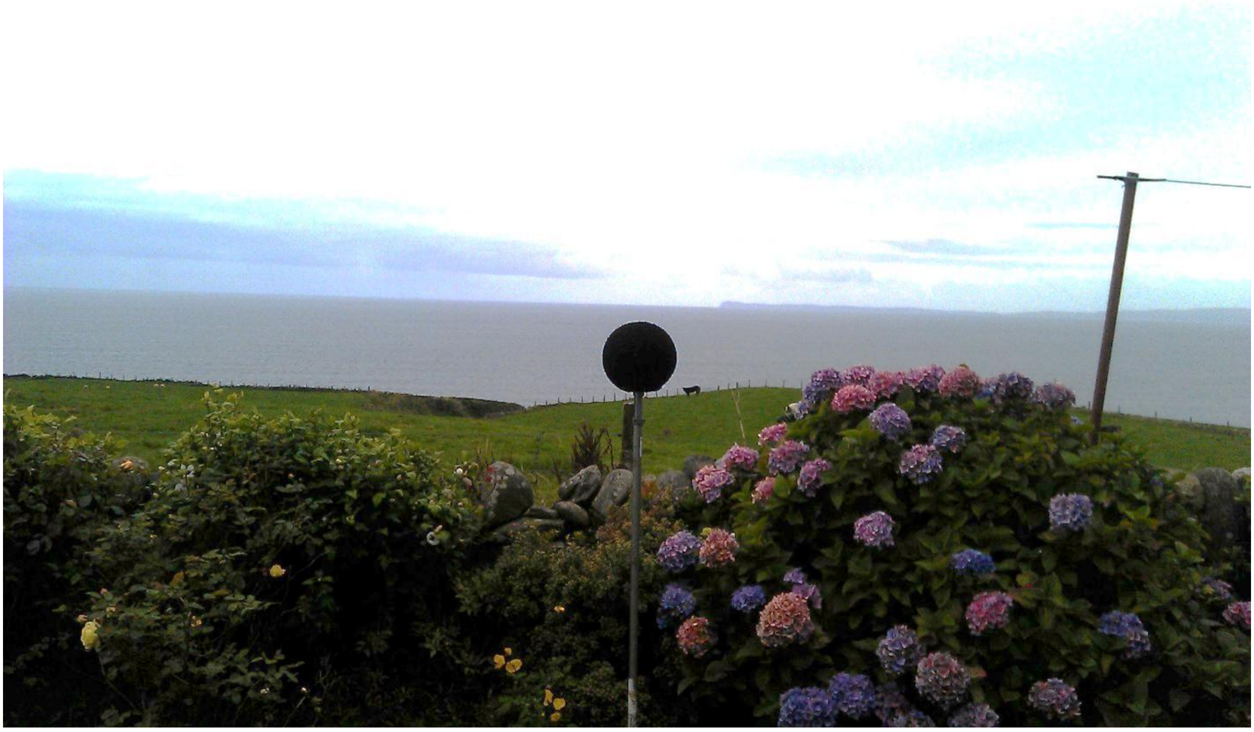


Table C2 – Information on the measurement location, equipment and noise data at Drum Farm.

Measurement Location	Drum Farm
Measurement Location Description	The monitoring location at Drum Farm was selected as being representative of background noise levels at residential properties to the south of the proposed Development, but far enough away from the existing Tangy wind farm not to be affected by noise from the existing operational turbines. The A83 runs at a distance of approximately 250 m to the southwest of the monitoring position. The monitoring equipment was located in a field, adjacent to the field boundary, at a distance of approximately 150 m to the northeast of Drum Farm. There were no acoustically reflective surfaces within 3.5 m of the monitoring location. The monitoring equipment was located adjacent to the southernmost field boundary, approximately halfway along the length of the field boundary. This location was selected so as to be as far as possible from both the water course that runs along the north-western field boundary (at a distance of approximately 70 m from the monitoring position) and the two wind turbines that are located at Drum Farm, approximately 100 m to the west of the monitoring position. Whilst the field in which the meter was located did not contain any livestock at the time that the meter was installed or removed, it is understood that for a short time during the noise survey, there was livestock in the field while being moved to another part of the farm. The noise monitoring equipment was fenced off from the field during this time. Noise sources that were audible at the monitoring location during the installation and collection of the equipment included farm machinery in use in the neighbouring fields and very occasional road traffic on the A83 and the minor local roads. No noise from the wind turbines at Drum Farm or the water course to the northwest of the monitoring position was audible during installation or collection of the equipment. SLM Location:167140, 625475.

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-31	00910448	30/08/2013
Pre-amplifier	Rion NH-21	02286	30/08/2013
Microphone	Rion UC53A	101792	30/08/2013
Calibrator	B&K 4231	3000377	21/12/2012
SLM Range	20 – 110 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
1	13/09/2013 11:00	09/10/2013 10:00	93.9	93.8	-0.1	No significant drift

Data Exclusions
Data recorded at this location was excluded during periods of rainfall and during wind directions of between 155 and 270 degrees, as it was observed that under these wind directions, baseline noise measurements were marginally higher than during other periods. This corresponded to downwind conditions from the turbines at the farm and therefore minimised the influence of that source on the measurements.

Figure C4 View of the monitoring location at Drum Farm looking southwest.

Figure C5 View of the monitoring location at Drum Farm looking west.

Figure C6 View of the monitoring location at Drum Farm looking northwest.

Table C3 – Information on the measurement location, equipment and noise data at Gobagrennan.

Measurement Location	Gobagrennan
Measurement Location Description	An individual residential property located to the east of the proposed development. The monitoring location at Gobagrennan was selected as being representative of the residential properties to the east of the proposed development, inland from the coast and in the vicinity of Lussa Loch. The monitoring position was located in the garden area of the property, approximately 15 m to the west of the residential building, approximately 20 m from the burn that runs to the north of the residential property and approximately 280 m to the west of the dam at the end of Lussa Loch. Forestry consisting of mature evergreen trees was located at a distance of approximately 100m to the west of the monitoring location. The monitoring equipment was situated on a small patio area in the middle of the garden at the request of the property owner. There were no acoustically reflective surfaces (other than the ground) within 3.5 m of the monitoring equipment. Noise sources that were audible at this location during installation and removal of the monitoring equipment included the breeze in the trees, water flow in the burn, occasional dogs barking, very occasional road traffic on the lane that runs past the property and birdsong. Due to battery failures at this location, the meter was restarted when the remaining meters were collected, therefore the monitoring at this location covered a slightly different period than the other monitoring positions. SLM Location:170591, 628598.

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-32	00630481	10/06/2013
Pre-amplifier	Rion NH-21	09098	10/06/2013
Microphone	Rion UC-53A	305115	10/06/2013
Calibrator	B&K 4231	3000377	21/12/2012
SLM Range	20 – 110 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
1	13/09/2013 12:00	25/09/2013 03:40	94.0	93.8	-0.2	No significant drift
2	09/10/2013 11:10	12/10/2013 21:00	93.8	93.9	0.1	No significant drift

Data Exclusions
Data recorded at this location was excluded during periods of rainfall.

Figure C7 View of the monitoring location at Gobagrennan looking east.

Figure C8 View of the monitoring location at Gobagrennan looking west.

Figure C9 View of the monitoring location at Gobagrennan looking north.

Table C4 – Information on the measurement location, equipment and noise data at Corrylach.

Measurement Location	Corrylach
Measurement Location Description	A residential property to the east of the proposed development site and adjacent to the north end of Lussa Loch. The monitoring location at Corrylach was selected as being representative of baseline noise levels at Corrylach and the holiday property at the north end of Lussa Loch. The monitoring position was located within the garden area at a distance of approximately 20 m from the residential property at Corrylach, approximately 80 m from the forestry (consisting of mature evergreen trees) to the west of the property and approximately 200 m from Lussa Loch. The monitoring equipment was positioned roughly in the middle of the garden area in order to be as far as possible from the burns that run along the north and south sides of the garden area, at distances of approximately 20 m and 25 m from the monitoring location respectively. There were no acoustically reflective surfaces within 3.5 m of the monitoring location. Noise sources that were audible at this location during installation and removal of the monitoring equipment included the breeze in the trees, chickens and a cockerel that are kept in the garden area of the property, and some water flow noise in the burns adjacent to the property. SLM Location: 170526, 630384.

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Rion NL-32	01030533	19/02/2013
Pre-amplifier	Rion NH-21	08179	19/02/2013
Microphone	UC-53A	304789	19/02/2013
Calibrator	B&K 4231	3000377	21/12/2012
SLM Range	20 – 110 dB(A)		

File	Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
1	13/09/2013 12:30	03/10/2013 09:00	93.9	93.8	-0.1	No significant drift

Data Exclusions
Data recorded at this location was excluded during periods of rain and periods that were identified from the time histories as being affected by water flow noise.

Figure C10 View of the monitoring location at Corrylach looking east.

Figure C11 View of the monitoring location at Corrylach looking south.

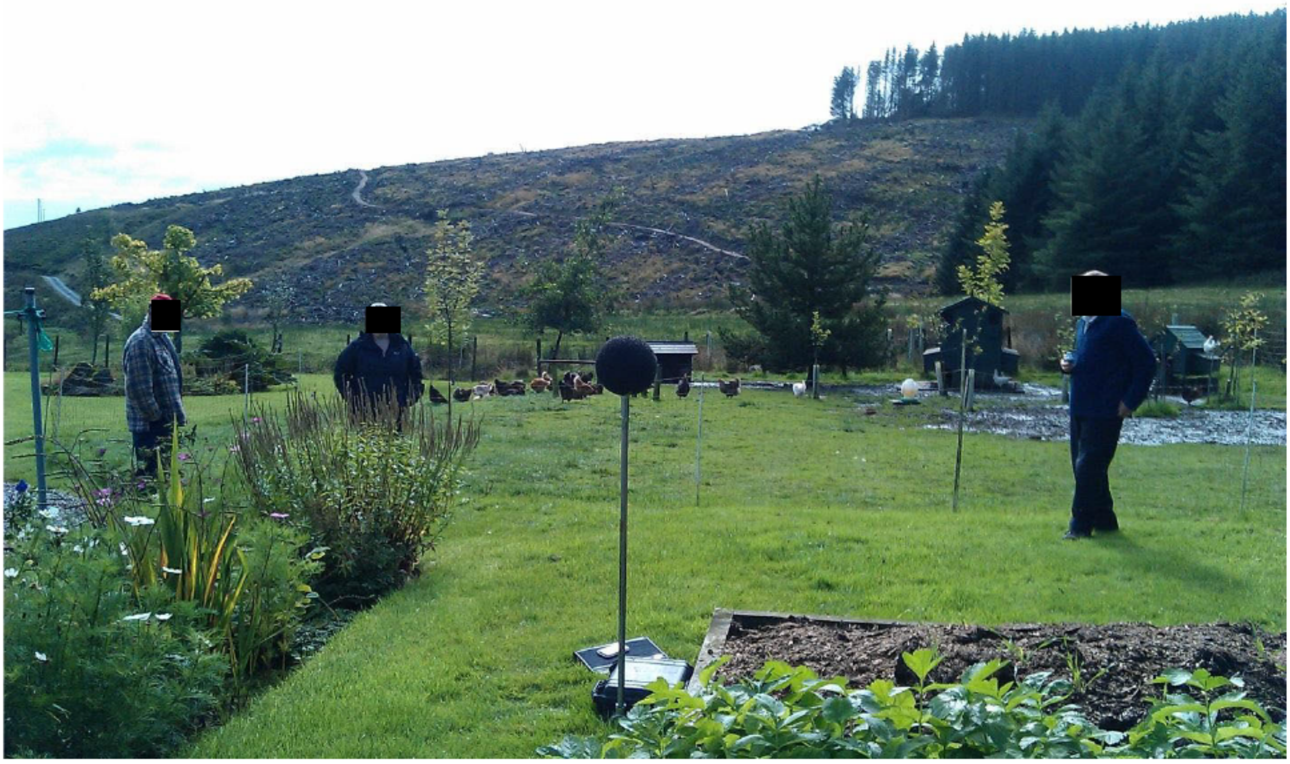


Figure C12 View of the monitoring location at Corrylach looking north.

Annex D – Wind Speeds and Directions

Figure D1 Wind speed and direction range during all quiet daytime periods at Killocraw, Drum Farm and Corrylach.

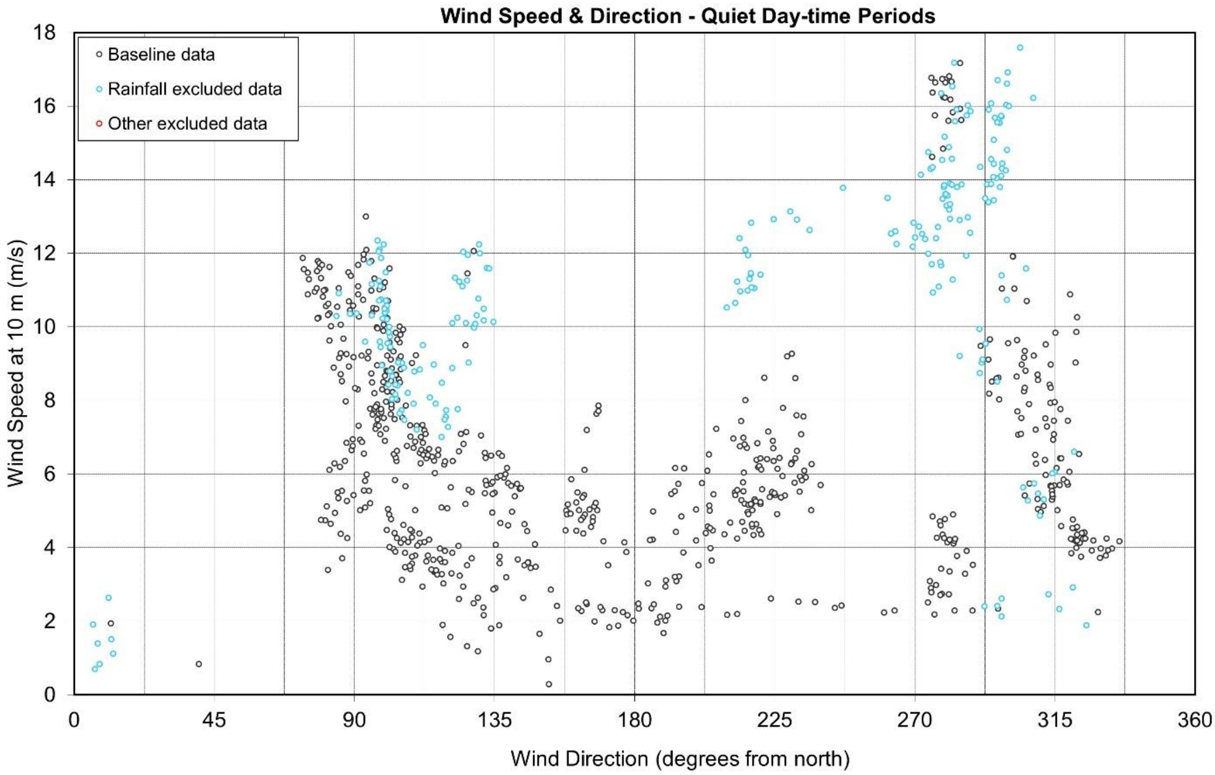


Figure D2 Wind speed and direction range during all night-time at Killocraw, Drum Farm and Corrylach

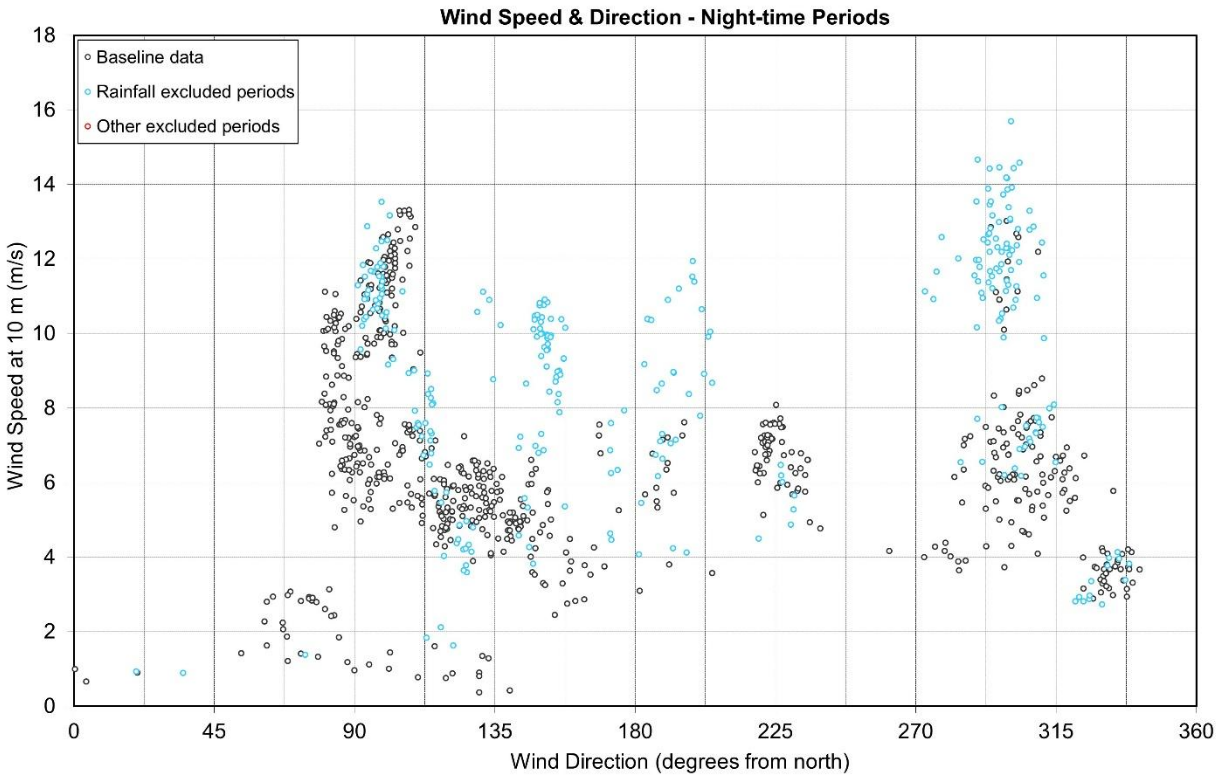


Figure D3 Wind speed and direction range during all quiet daytime periods at Gobagrennan.

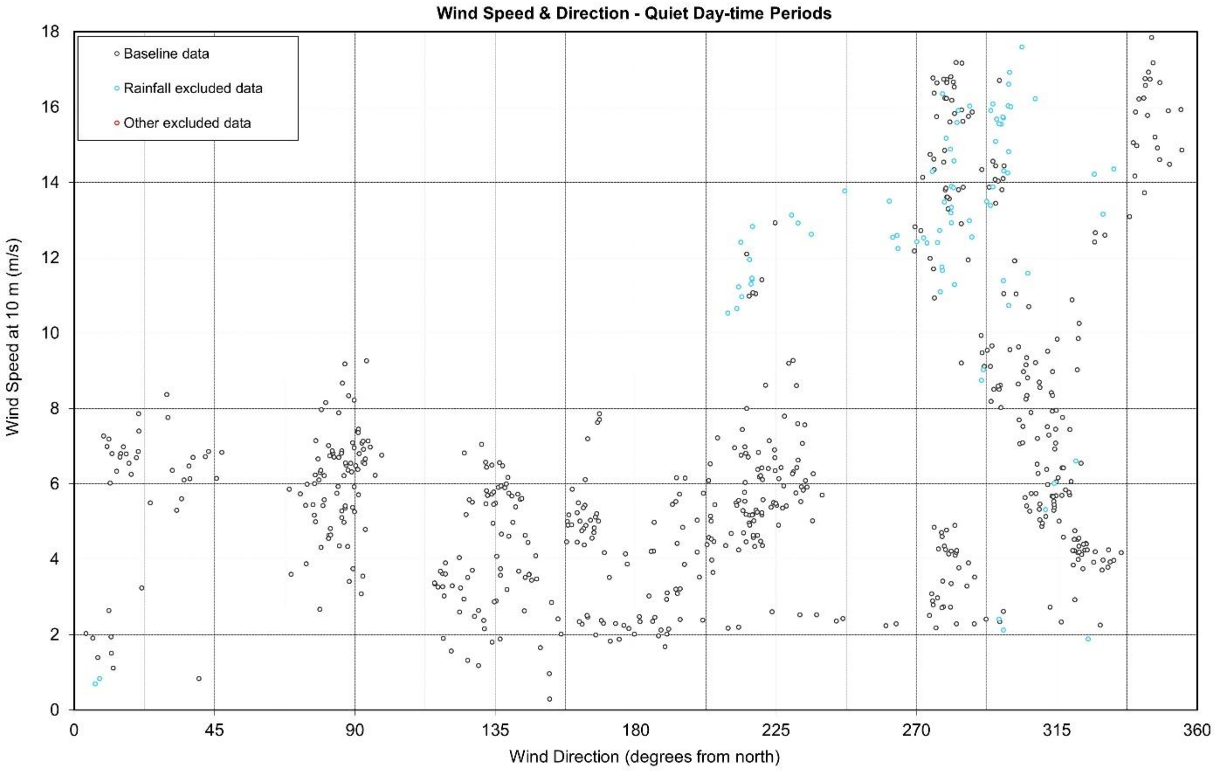
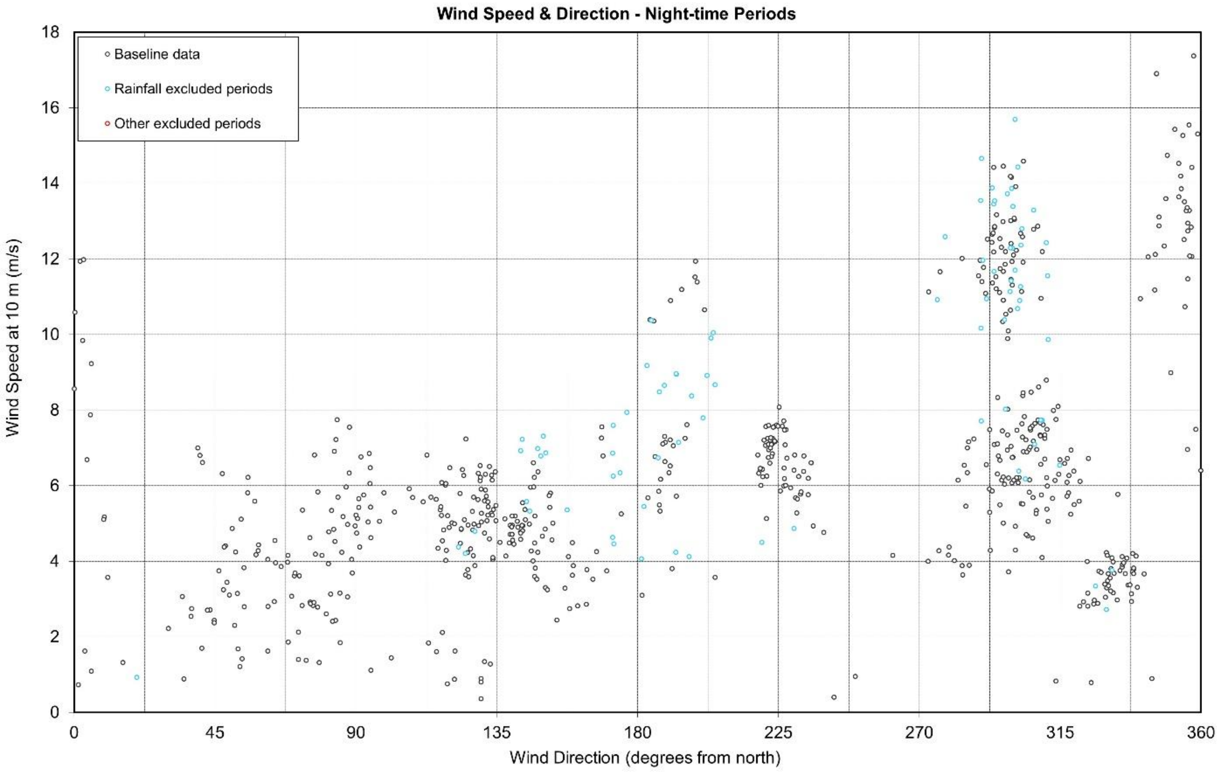


Figure D4 Wind speed and direction range during all night-time at Gobagrennan.



Annex E – Background Noise

Figure E1 Chart of background noise levels against wind speeds and best fit curve to the data, for Killocraw during quiet daytime periods.

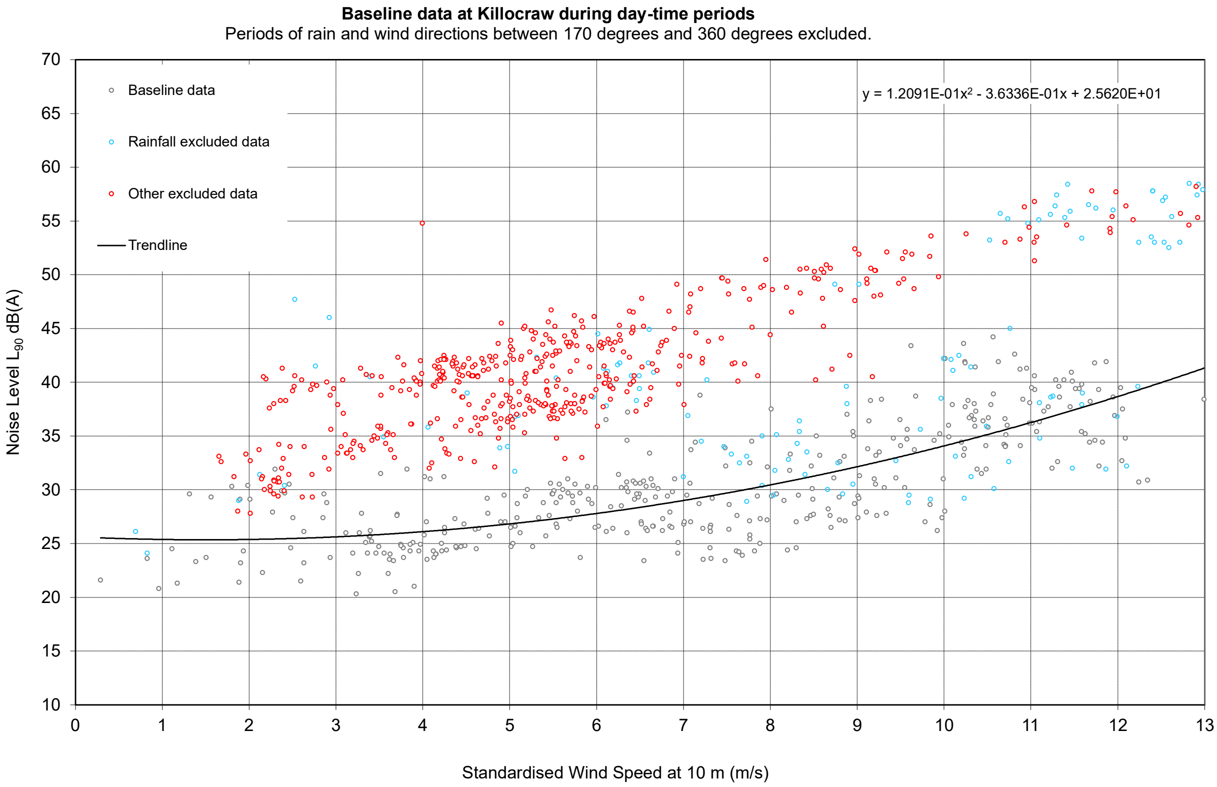


Figure E2 Chart of background noise levels against wind speeds and best fit curve to the data, for Killocraw during night-time periods.

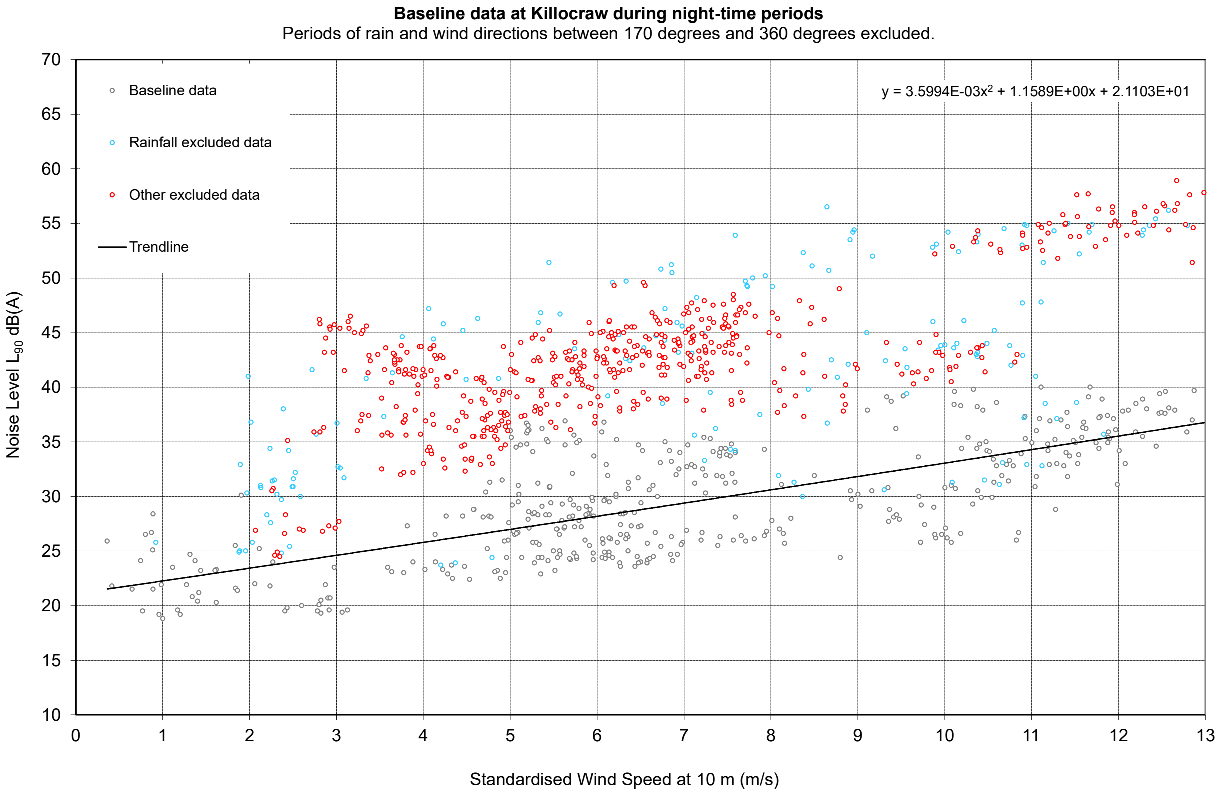


Figure E3 Chart of background noise levels against wind speeds and best fit curve to the data, for Drum Farm during quiet daytime periods.

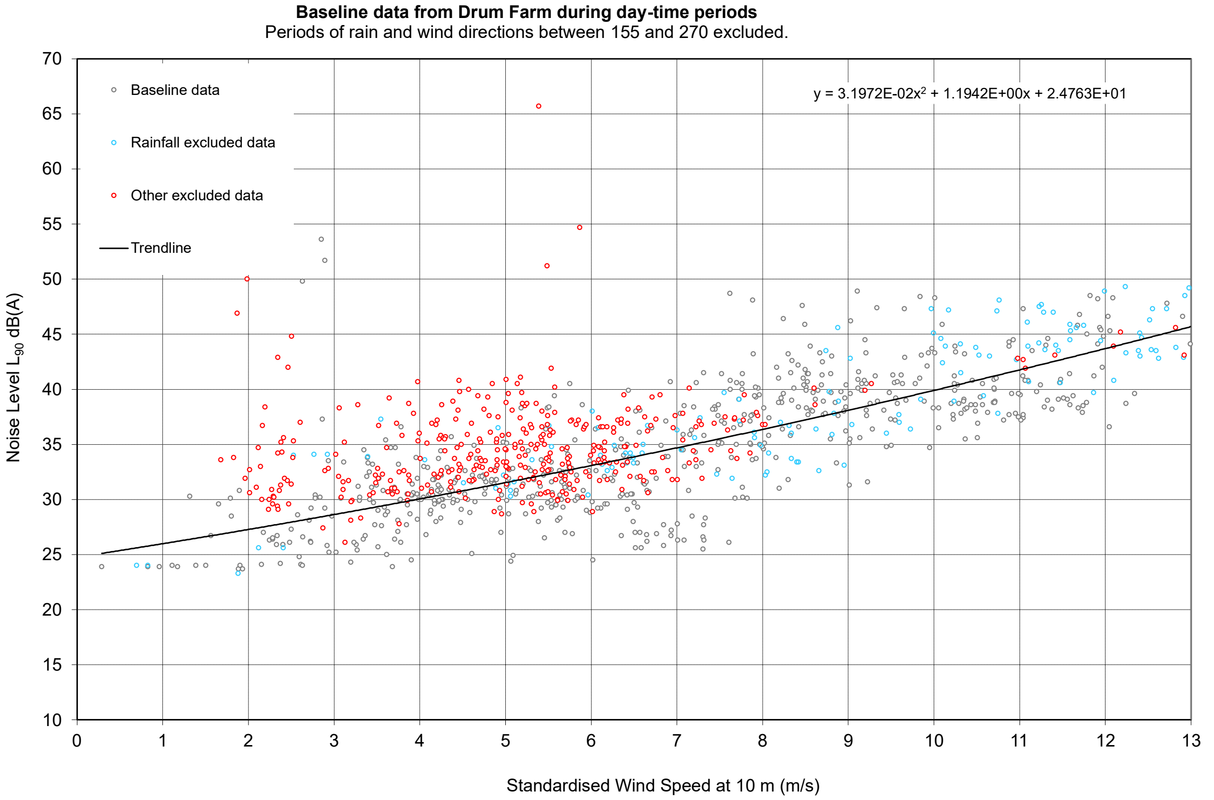


Figure E4 Chart of background noise levels against wind speeds and best fit curve to the data, for Drum Farm during night-time periods

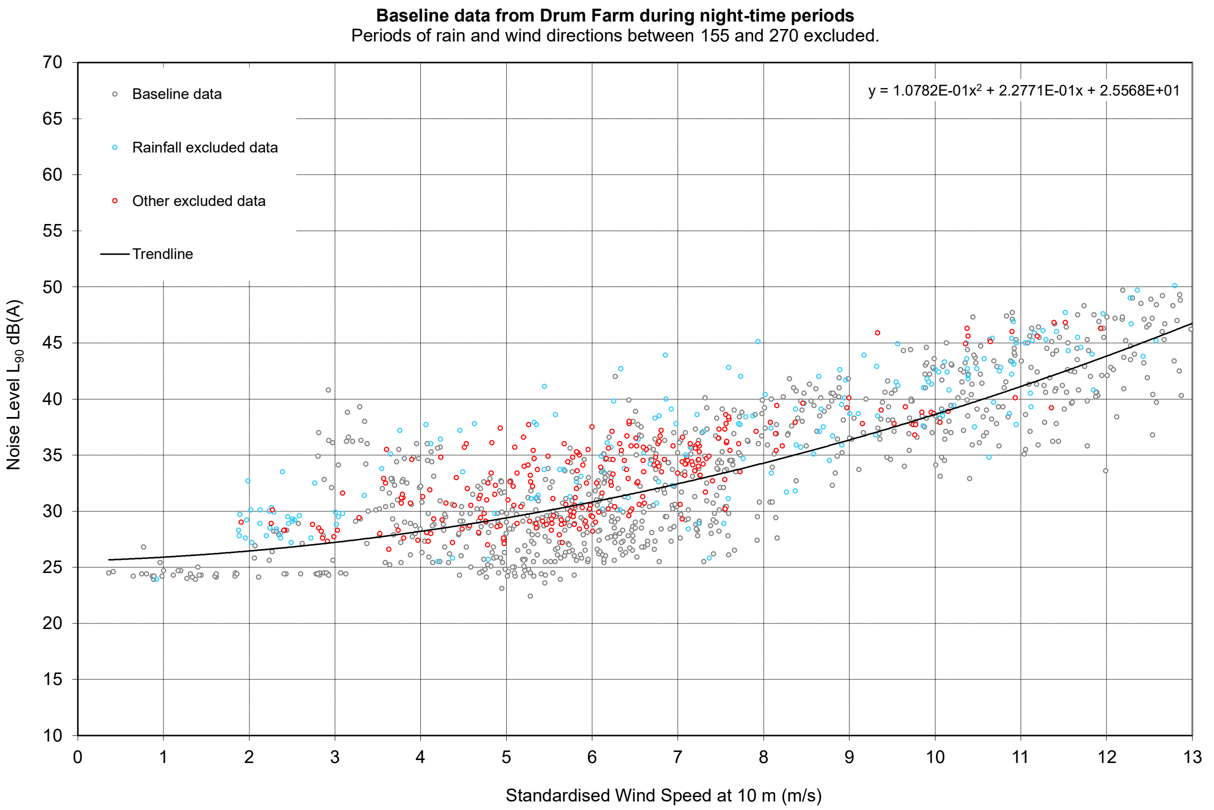


Figure E5 Chart of background noise levels against wind speeds and best fit curve to the data, for Gobragennan during quiet daytime periods.

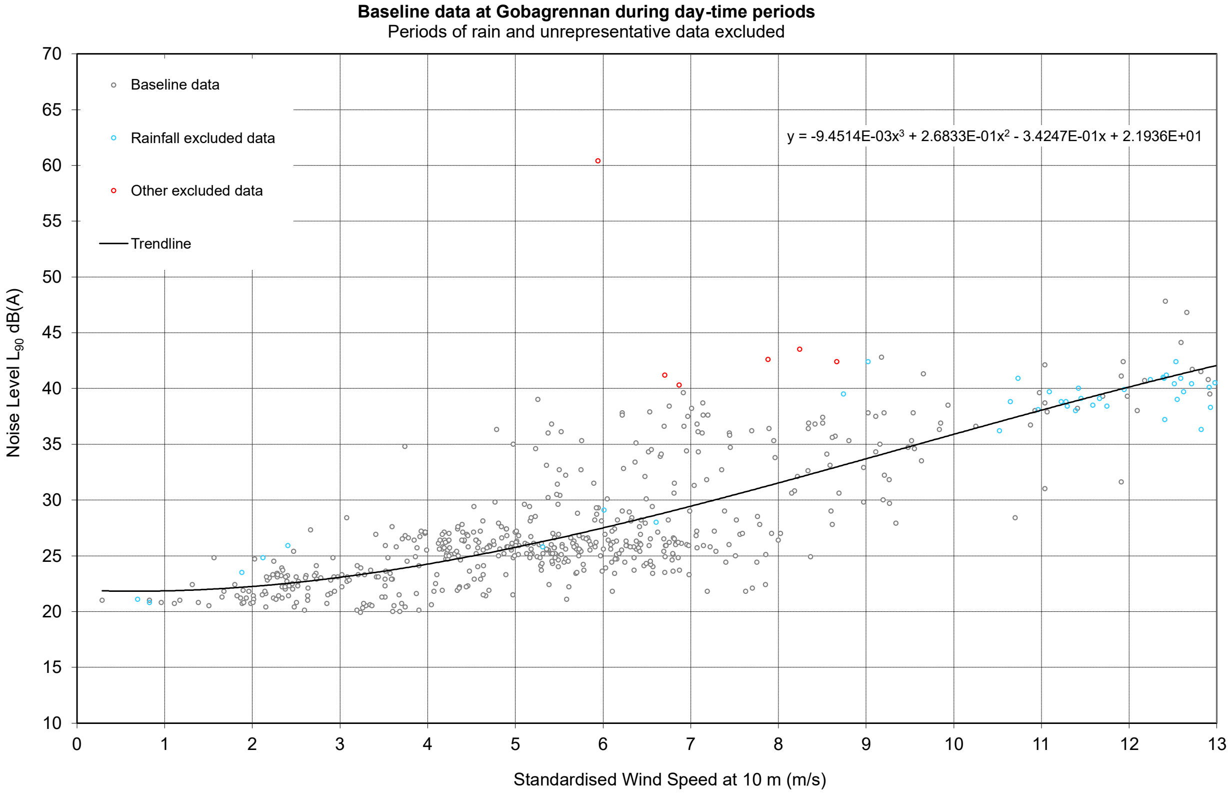


Figure E6 Chart of background noise levels against wind speeds and best fit curve to the data, for Gobragennan during night-time periods

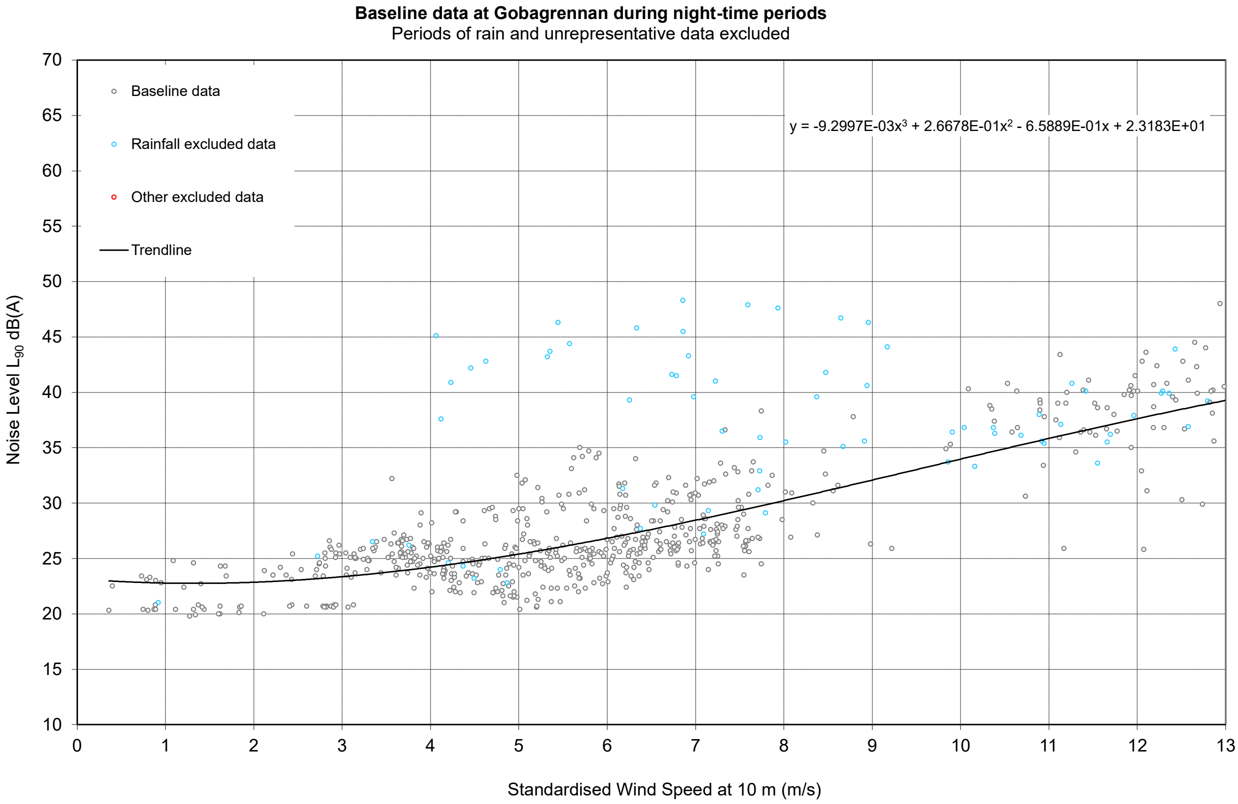


Figure E7 Chart of background noise levels against wind speeds and best fit curve to the data, for Corrylach during quiet daytime periods.

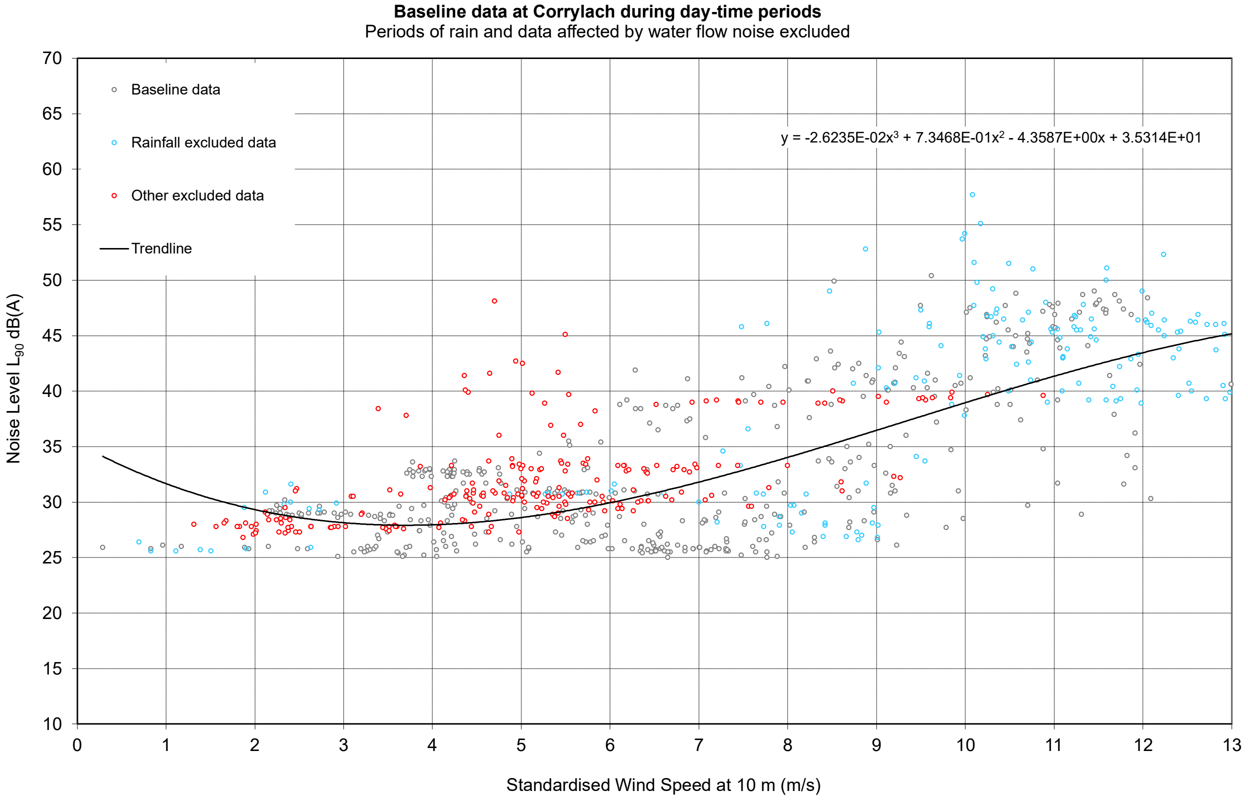
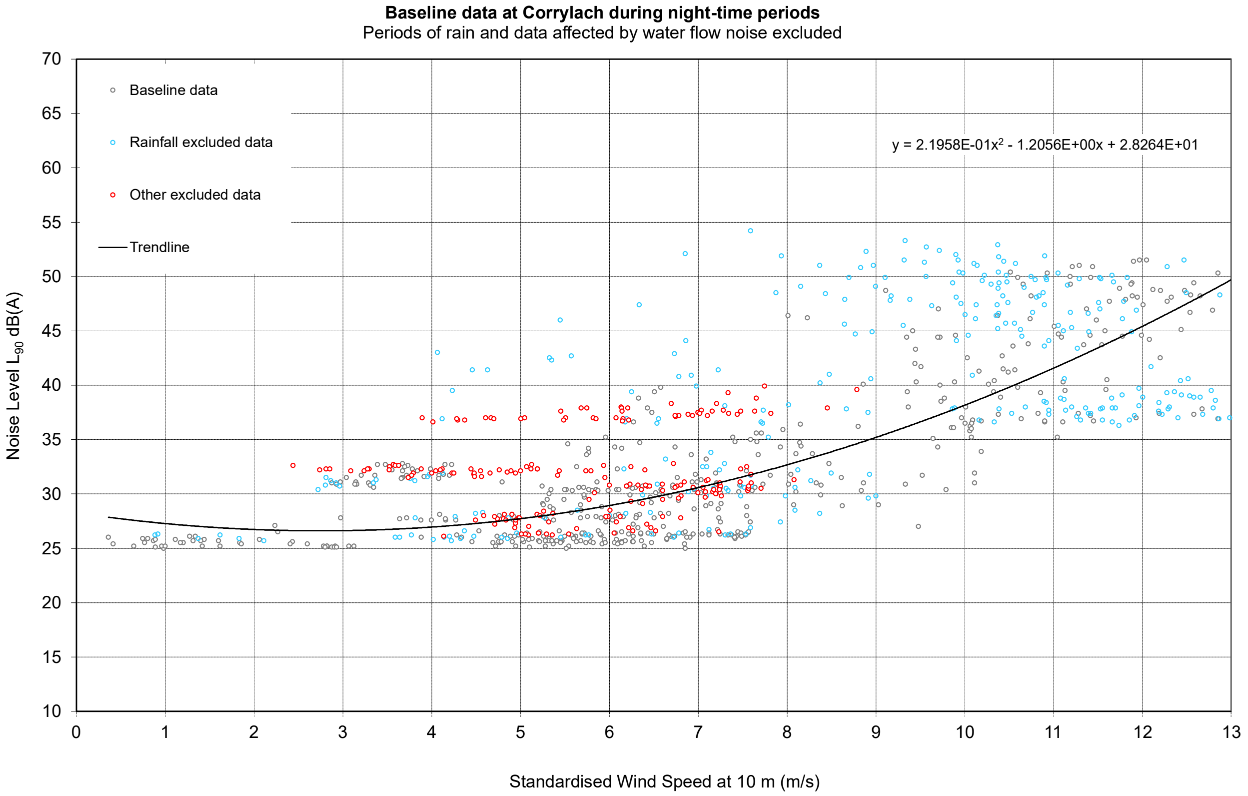


Figure E8 Chart of background noise levels against wind speeds and best fit curve to the data, for Corrylach during night-time periods



Annex F – Wind Speed Calculations

F1. An important consideration when specifying the sound power outputs of wind turbines is the fact that wind speed varies with height above the ground. This effect is commonly termed 'wind shear'. Therefore, if the wind speed on a site is characterised in terms of, say, the wind speed measured at ten metres above ground level, then some means must be available for converting this ten-metre height wind speed to whatever the hub height of the proposed turbine will be. This is important because it is this hub height wind speed (i.e. the wind speed experienced by the rotor of the wind turbine) that determines the actual sound power radiated by that turbine.

F2. The example of a ten-metre height wind speed is selected here because this height is frequently adopted as a 'reference'. For example, in ETSU-R-97 [1] the wind speed dependent background noise levels are specified as a function of ten metre height site wind speeds. Likewise, the declared sound power data measured in accordance with the internationally adopted standard for the measurement of wind turbine sound power output, IEC61400-11 [2], is also referenced to a ten-metre height wind speed.

F3. The ground roughness length, z, indicates the degree to which wind is slowed down by friction as it passes close to the ground: the rougher the ground, the more the wind is slowed down and the larger the roughness length. Table 11 of ETSU-R-97 gives examples of roughness lengths, as repeated here in Table F.1. Figure F.1 shows the wind speed profiles corresponding to the four ground roughness lengths given in Table F1.

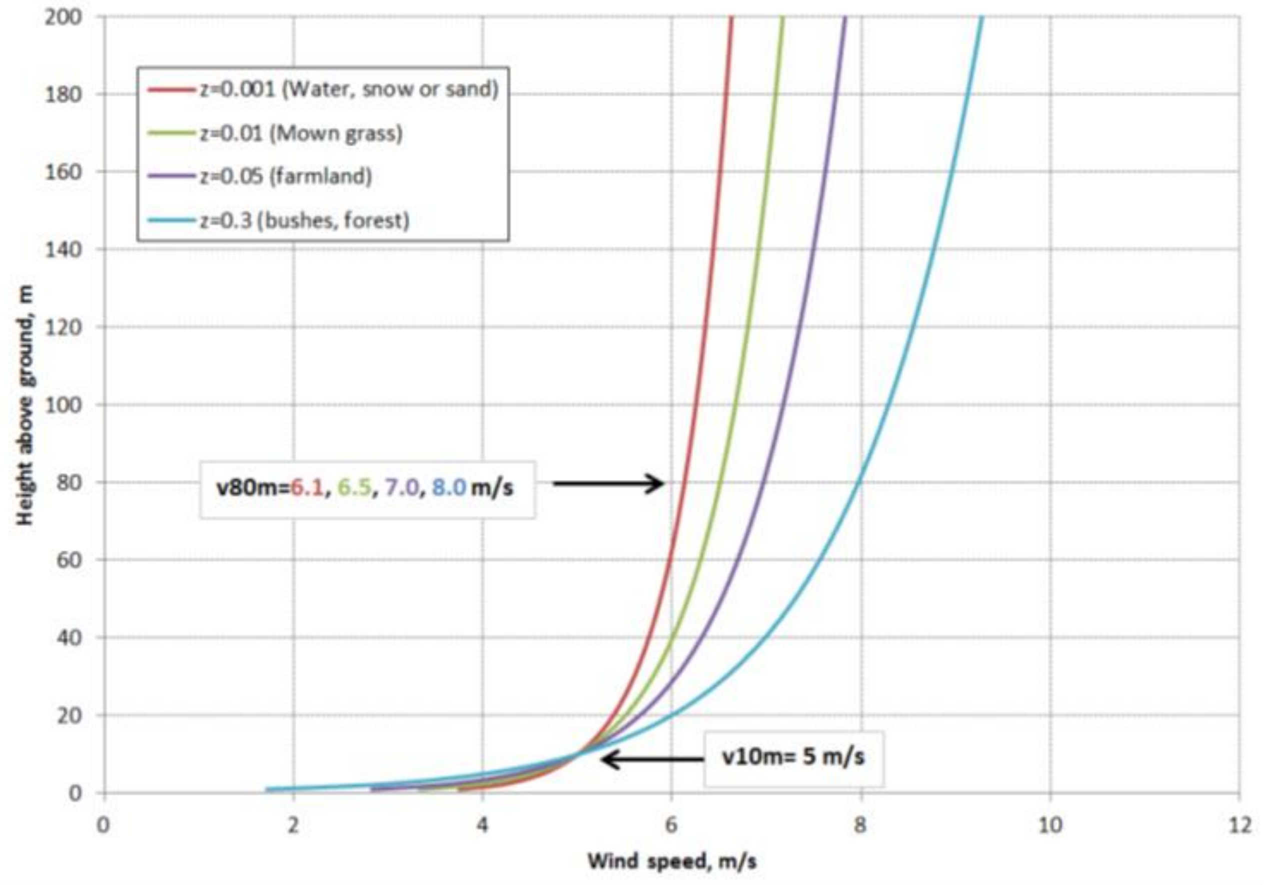
F4. However, it has been found from measurements that the influence of the ground may not be the only factor affecting the variation of wind speed as a function of height above the ground. Another key factor can be the amount of turbulence in the atmosphere itself.

F5. Generally speaking, under a typical daytime meteorological scenario, the atmosphere lying above the ground will exhibit what is termed 'neutral' characteristics. In such cases the atmosphere itself has little effect on the wind speed profile which is then controlled primarily by ground roughness. However, under certain conditions, typically on a summer's evening following a warm day, the radiative effects of the ground can cool the air lying close to the earth at a rate faster than the convective cooling of the air lying above. This can result in a highly stable atmosphere, one of the characteristics of which is a pronounced wind shear effect. This means that the relative difference between the wind speed at ten metres height and that at hub height during affected evening/night-time periods may be significantly greater than the difference which typically exists during daytime periods or other 'neutral' conditions.

Table F1 - Table 11 of ETSU-R-97 showing the typical roughness lengths associated with different terrain types

Type of Terrain	Roughness Length, z (metres)
Water, snow or sand surfaces	0.0001
Open, flat land, mown grass, bare soil	0.01
Farmland with some vegetation (reference)	0.05
Suburbs, towns, forests, many trees and bushes	0.3

Figure F1 Wind speed profiles calculated for the four different ground roughness lengths listed in Table F.1. The figure adopts a fixed wind speed at ten metres height of v10=5 ms-1 then presents the calculated wind speeds at other heights as the curved lines. The calculated wind speeds at 80 metres height corresponding to the assumed U10=5 ms-1 are also presented as numerical values, ranging from U80=6.1 ms-1 for a ground roughness length of z=0.001 metres to U80=8.0 ms-1 for ground roughness length of z=0.3 metres.



F6. When undertaking noise certification measurements of wind turbine sound power outputs, the relevant procedure applies a standard means of converting between hub height and ten metres height wind speeds. This involves using a 'standard' roughness length of 0.05 metres in Equation F1, regardless of what the actual roughness length seen on the test site may have been. This 'normalisation' procedure is adopted to ensure direct comparability between test results for different turbines. However, when this standardised data is subsequently used to calculate the sound power radiated from an installed turbine on an actual wind farm site, it is important to convert between ten metres height wind speeds and hub height wind speeds using the actual wind speed differences experienced on the site itself. These hub height wind speeds may well be different from those calculated by assuming the standard 0.05 metres ground roughness length.

F7. The relevance of this conversion between wind speeds at ten metres height and wind speeds at hub height has come under increasing scrutiny with the acknowledgement that, on some sites, the wind shear (i.e. the increase in wind speed with increasing height above ground level) can vary significantly between daytime and evening/night-time periods. This difference occurs for the reasons discussed above concerning the radiative cooling effects of the earth on the lower levels of air. When this effect occurs, the wind speed experienced by the turbine blades at night can be significantly higher than that derived using either a 'standard' assumed roughness length based on the characteristics of the general terrain, or from using on a roughness length or shear factor based on longer term averaged measurements of the difference in wind speeds measured at two different heights. This issue, and the manner in which it has been accounted for in the case of the proposed development, is discussed in the following section.

Approach

F8. The site of the proposed development has a temporary 80 metre meteorological (met) mast installed which measured wind conditions at various heights as follows:

- 80 metre Wind speed
- 78 metre Wind direction
- 60 metre Wind speed
- 58 metre Wind direction
- 40 metre Wind speed

F9. Wind speeds are needed at a height of ten metres for correlation with measured noise data as specified in ETSU-R-97. ETSU-R-97 also requires the noise assessment be performed with a wind speed maximum of no more than 12 m/s at ten metres height. Whilst it would be possible to use the direct measurement of wind speeds at a height of ten metres, this approach has been questioned due to potential differences in the wind shear profile during the evenings and night times when compared to the daytime. In accordance with the preferred methodology set out in the Institute of Acoustic Good Practice Guide [3], all ten metre wind speed data is calculated from those which will be directly experienced by the wind turbines. Wind speeds are therefore related directly to those at hub height and calculated to be at ten metres height assuming reference conditions. Reference conditions are those used when reporting the measured and/or warranted sound power levels of the wind turbines and assume a ground roughness length of 0.05 metre. The process used to calculate the ten metres height wind speeds is therefore described below.

Methodology

F10. ETSU-R-97 specifies that where measurements are not made using a ten-metre met mast, measurements at other heights may be used to provide ten metre height wind speeds by calculation. Equation F1 is given in ETSU-R-97 for this purpose.

$$U_1 = U_2 \cdot \frac{\ln\left(H_1 / z \right)}{\ln\left(H_2 / z \right)}$$

Where:

H1	The height of the wind speed to be calculated (10 metres)
H2	The height of the measured wind speed
U1	The wind speed to be calculated
U2	The measured wind speed
z	The roughness length (0.05 metres in the case of reference conditions)

F11. Equation F1 is of the same form as that given in BS EN 61400 11:2003 [2] for calculating ten metre wind speeds related to hub height wind speeds when providing source noise emission data for wind turbines. ETSU-R-97 suggests that the roughness length may be calculated from wind speed measurements at two heights, by inverting equation F1. Alternatively, wind shear can be described by the wind shear exponent according to equation F2 as follows:

$$U = U_{ref} \cdot \left[\frac{H}{H_{ref}} \right]^m$$

Where:

U	calculated wind speed.
Uref	measured wind speed
H	height at which the wind speed will be calculated
Href	height at which the wind speed is measured
m	shear exponent

F12. In this case, the wind shear exponent may be calculated from wind speed measurements at two heights, by inverting equation F2.

F13. Data from the met. mast were available for the duration of the survey. These data were used to perform a calculation of the shear exponent found between the highest two wind speed measurements of 80 and 60 metres for every ten-minute period. Where wind speeds were the same at both heights or lower at greater height, the shear exponent was assumed to be zero. The shear exponent so calculated for every ten-minute period were then used to calculate the hub height (125 m) wind speed from that measured at 80 metres using equation F2. Equation F1 was then used to calculate a ten-metre height wind speed from the hub height wind speed every ten minutes assuming the reference roughness length of 0.05 metres.

Conclusions

F14. By using this method, measured background noise levels were correlated to ten metre wind speeds calculated from wind speeds at hub height. Any likely difference in the shear profile during the 24 hours of the day will be accounted for within the method and be reflected in the resulting ten metre wind speed data.

F15. The method used to calculate ten metre wind speeds from those at hub height is the same as that used when deriving noise emission data for the turbines. Because the same method has been used, direct comparison of background noise levels, noise limits and predicted turbine noise immission levels may be undertaken. This method is consistent with guidance published in the Institute of Acoustic Bulletin Good Practice Guide [3].

References for Wind Speed Calculations

[1] ETSU-R-97, The Assessment and Rating of Noise from Wind Farms, Final Report for the Department of Trade & Industry, September 1996. The Working Group on Noise from Wind Turbines.

[2] IEC 61400 11:2003 Wind turbine generator systems - Part 11: Acoustic noise measurement techniques.

[3] A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.

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