5.5.2 Table 13 then shows the predicted noise levels for the combination of the proposed Development and the existing Arecleoch turbines, therefore representing the total noise levels for the extended Arecleoch Windfarm. The predicted noise levels of Table 13 do not exceed 36 dB L_{A90} at any wind speed or location.

Table 12 - Predicted $L_{A90,T}$ windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the proposed Development (Arecleoch Windfarm Extension) alone.

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	14.2	18.6	21.4	22.0	22.5	22.5	22.5	22.5	22.5
Bellimore-on-Tig	17.3	21.7	24.5	25.1	25.6	25.6	25.6	25.6	25.6
Bents Farm	19.4	23.8	26.6	27.2	27.7	27.7	27.7	27.7	27.7
Brooklyn	14.6	19.0	21.8	22.4	22.9	22.9	22.9	22.9	22.9
Cairnlea	19.9	24.3	27.1	27.7	28.2	28.2	28.2	28.2	28.2
Chirmorrie	21.0	25.4	28.2	28.8	29.3	29.3	29.3	29.3	29.3
Craigengells	17.5	21.9	24.7	25.3	25.8	25.8	25.8	25.8	25.8
Dochroyle Cottage	18.7	23.1	25.9	26.5	27.0	27.0	27.0	27.0	27.0
Dochroyle Farm	18.7	23.1	25.9	26.5	27.0	27.0	27.0	27.0	27.0
Duisk Lodge	16.5	20.9	23.7	24.3	24.8	24.8	24.8	24.8	24.8
East Altercannoch	17.0	21.4	24.2	24.8	25.3	25.3	25.3	25.3	25.3
Farden	21.9	26.3	29.1	29.7	30.2	30.2	30.2	30.2	30.2
Ferngate Cottage	20.1	24.5	27.3	27.9	28.4	28.4	28.4	28.4	28.4
Glenour	25.4	29.8	32.6	33.2	33.7	33.7	33.7	33.7	33.7
Gowlands	15.8	20.2	23.0	23.6	24.1	24.1	24.1	24.1	24.1
Gowlands Terrace	15.5	19.9	22.7	23.3	23.8	23.8	23.8	23.8	23.8
Kildonan Courtyard	16.4	20.8	23.6	24.2	24.7	24.7	24.7	24.7	24.7
Kilrenzie	25.9	30.3	33.1	33.7	34.2	34.2	34.2	34.2	34.2
Laggish	17.6	22.0	24.8	25.4	25.9	25.9	25.9	25.9	25.9
Laigh Altercannoch	14.9	19.3	22.1	22.7	23.2	23.2	23.2	23.2	23.2
Queensland Caravan Park	17.8	22.2	25.0	25.6	26.1	26.1	26.1	26.1	26.1
Scaurhead	16.5	20.9	23.7	24.3	24.8	24.8	24.8	24.8	24.8
The Craigs	15.4	19.8	22.6	23.2	23.7	23.7	23.7	23.7	23.7
The Manse	16.8	21.2	24.0	24.6	25.1	25.1	25.1	25.1	25.1
Ward of Cairnlea	17.8	22.2	25.0	25.6	26.1	26.1	26.1	26.1	26.1
West Altercannoch	17.7	22.1	24.9	25.5	26.0	26.0	26.0	26.0	26.0
Wheeb	23.2	27.6	30.4	31.0	31.5	31.5	31.5	31.5	31.5
White Cairn	19.1	23.5	26.3	26.9	27.4	27.4	27.4	27.4	27.4

Table 13 - Predicted $L_{A90,T}$ windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the combination of the proposed Development and the existing Arecleoch turbines.

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	24.5	29.3	31.6	31.7	31.8	31.8	31.8	31.8	31.8
Bellimore-on-Tig	27.4	32.1	34.5	34.6	34.7	34.7	34.7	34.7	34.7
Bents Farm	21.2	25.8	28.4	28.8	29.2	29.2	29.2	29.2	29.2

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Brooklyn	17.3	21.9	24.5	24.9	25.2	25.2	25.2	25.2	25.2
Cairnlea	21.6	26.1	28.7	29.2	29.5	29.5	29.5	29.5	29.5
Chirmorrie	25.9	30.6	33.0	33.3	33.5	33.5	33.5	33.5	33.5
Craigengells	19.8	24.4	26.9	27.3	27.7	27.7	27.7	27.7	27.7
Dochroyle Cottage	22.0	26.6	29.1	29.4	29.7	29.7	29.7	29.7	29.7
Dochroyle Farm	22.0	26.6	29.1	29.5	29.8	29.8	29.8	29.8	29.8
Duisk Lodge	18.8	23.4	26.0	26.4	26.7	26.7	26.7	26.7	26.7
East Altercannoch	20.0	24.6	27.2	27.5	27.8	27.8	27.8	27.8	27.8
Farden	23.8	28.4	31.0	31.4	31.8	31.8	31.8	31.8	31.8
Ferngate Cottage	22.2	26.7	29.3	29.7	30.1	30.1	30.1	30.1	30.1
Glenour	28.0	32.5	35.1	35.5	35.8	35.8	35.8	35.8	35.8
Gowlands	18.4	23.0	25.5	25.9	26.2	26.2	26.2	26.2	26.2
Gowlands Terrace	18.1	22.7	25.3	25.7	26.0	26.0	26.0	26.0	26.0
Kildonan Courtyard	18.8	23.4	26.0	26.4	26.7	26.7	26.7	26.7	26.7
Kilrenzie	28.1	32.7	35.3	35.7	36.0	36.0	36.0	36.0	36.0
Laggish	20.7	25.4	27.9	28.2	28.5	28.5	28.5	28.5	28.5
Laigh Altercannoch	17.5	22.1	24.6	25.0	25.3	25.3	25.3	25.3	25.3
Queensland Caravan Park	20.0	24.6	27.2	27.6	27.9	27.9	27.9	27.9	27.9
Scaurhead	18.8	23.4	26.0	26.4	26.7	26.7	26.7	26.7	26.7
The Craigs	17.8	22.4	25.0	25.4	25.7	25.7	25.7	25.7	25.7
The Manse	18.9	23.4	26.0	26.4	26.8	26.8	26.8	26.8	26.8
Ward of Cairnlea	20.1	24.7	27.3	27.7	28.0	28.0	28.0	28.0	28.0
West Altercannoch	20.2	24.8	27.4	27.8	28.1	28.1	28.1	28.1	28.1
Wheeb	26.8	31.4	33.9	34.3	34.5	34.5	34.5	34.5	34.5
White Cairn	20.9	25.4	28.1	28.5	28.9	28.9	28.9	28.9	28.9

5.5.3 Table 14 shows predicted cumulative noise immission levels at each of the selected assessment locations for each standardised wind speed from 4 m/s to 12 m/s inclusive. These predictions are cumulative assuming all other windfarms are operating, as assumed above in Section 5.3, and that all receptors are downwind of all wind turbines at the same time, which is not possible in many cases. These cumulative noise levels are therefore unlikely to occur in practice. The Chirmorrie location was excluded and considered separately below as it would not be occupied if the Chirmorie Windfarm is constructed.

Table 14 - Predicted Cumulative $L_{A90,T}$ windfarm noise immission levels at each of the noise assessment locations as a function of standardised wind speed

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	25.0	29.9	32.4	32.5	32.6	32.6	32.6	32.6	32.6
Bellimore-on-Tig	27.7	32.5	34.9	35.1	35.1	35.1	35.1	35.1	35.1
Bents Farm	25.7	30.7	34.1	34.8	34.9	34.9	34.9	34.9	34.9
Brooklyn	25.2	30.2	33.8	34.5	34.6	34.6	34.6	34.6	34.6
Cairnlea	27.5	32.5	36.0	36.6	36.7	36.7	36.7	36.7	36.7

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Craigengells	25.6	30.6	34.1	34.8	34.9	34.9	34.9	34.9	34.9
Dochroyle Cottage	28.7	33.8	37.0	37.2	37.2	37.2	37.2	37.2	37.2
Dochroyle Farm	28.6	33.7	36.9	37.1	37.1	37.1	37.1	37.1	37.1
Duisk Lodge	25.8	30.8	34.4	35.2	35.2	35.2	35.2	35.2	35.2
East Altercannoch	26.7	31.8	35.2	35.8	35.8	35.8	35.8	35.8	35.8
Farden	26.1	30.8	34.0	34.6	34.7	34.7	34.7	34.7	34.7
Ferngate Cottage	27.6	32.6	36.0	36.6	36.7	36.7	36.7	36.7	36.7
Glenour	28.4	33.0	35.7	36.1	36.4	36.4	36.4	36.4	36.4
Gowlands	25.7	30.8	34.4	35.1	35.1	35.1	35.1	35.1	35.1
Gowlands Terrace	25.7	30.7	34.3	35.0	35.1	35.1	35.1	35.1	35.1
Kildonan Courtyard	25.5	30.5	34.1	34.8	34.8	34.8	34.8	34.8	34.8
Kilrenzie	28.5	33.1	35.8	36.2	36.5	36.5	36.5	36.5	36.5
Laggish	29.4	34.6	37.8	37.9	37.9	37.9	37.9	37.9	37.9
Laigh Altercannoch	25.1	30.1	33.7	34.4	34.4	34.4	34.4	34.4	34.4
Queensland Caravan Park	25.5	30.4	33.9	34.7	34.7	34.7	34.7	34.7	34.7
Scaurhead	26.0	31.0	34.6	35.4	35.4	35.4	35.4	35.4	35.4
The Craigs	25.8	30.9	34.4	35.1	35.2	35.2	35.2	35.2	35.2
The Manse	25.9	30.9	34.5	35.2	35.3	35.3	35.3	35.3	35.3
Ward of Cairnlea	26.6	31.6	35.1	35.8	35.8	35.8	35.8	35.8	35.8
West Altercannoch	26.3	31.3	34.8	35.4	35.4	35.4	35.4	35.4	35.4
Wheeb	27.4	32.1	34.7	35.1	35.3	35.3	35.3	35.3	35.3
White Cairn	27.3	32.3	35.9	36.6	36.7	36.7	36.7	36.7	36.7

5.6 ETSU-R-97 assessment

5.6.1 Figures E1 to E18 (Annex E) show the calculated windfarm noise immission levels at a sub-set of the most relevant and representative noise assessment locations for each of the locations considered in Tables 2 and 3. Predicted levels correspond to those already presented in Table 12 to 14 plotted as a function of standardised ten metre wind speed. The calculated noise immission levels are shown overlaid on the day-time and night-time noise limit curves. These limits curves have been derived by calculating best-fit regression lines through the measured background noise data to give the prevailing background noise curve required by ETSU-R-97. The noise limits have then been set either at the prevailing measured background level plus 5 dB or at the relevant fixed lower limit whichever is the greater.

5.6.2 The ETSU-R-97 noise limits assume that the wind turbine noise contains no audible tones. Where tones are present a correction is added to the measured or predicted noise level before comparison with the recommended limits. The audibility of any tones can be assessed by comparing the narrow band level of such tones with the masking level contained in a band of frequencies around the tone called the critical band. The ETSU-R-97 recommendations suggest a tone correction which depends on the amount by which the tone exceeds the audibility threshold and should be included as part of the consent conditions. The turbines to be used for this site will be chosen to ensure that the noise emitted will comply with the requirements of ETSU-R-97 including any relevant tonality corrections.

5.6.3 The ETSU-R-97 fixed part of the limit during the day-time should lie within the range from 35 dB(A) to 40 dB(A). The factors to be used to determine where in this range have been discussed above and are considered below:

- Number of properties: The area of the proposed Development and its immediate surroundings is generally of very low population density, with only a few isolated properties. The exception is the settlement at Barrhill with a larger number of properties: but the consideration of the fixed part of the limit is not relevant for these properties. Predicted noise levels from the proposed Development (Table 12) or in combination with the existing turbines of the Arecleoch Windfarm (Table 13) are below 30 dB(A) for these dwellings. Furthermore, these properties experience increased levels of background from water courses, the A714 and commercial activities.
- Duration and level of exposure: The charts of Annex E show the predicted levels from the proposed Development in relation to the range of measured baseline levels in quiet conditions during the day-time for key locations. It is apparent that these predictions are clearly below measured background levels for properties in and around Barrhill. For properties closer to the proposed Development, such as Glenour or Chirmorrie, the predicted noise levels from the proposed Development are comparable to the range of background noise levels measured. Although predicted cumulative noise levels are higher, they were predicted on a conservative basis which assumed simultaneous downwind propagation and the actual levels which occur in practice will be lower.
- Generation capacity: given the number and scale of existing windfarms in the area, the effect of having a limit at the lower end of the range of 35-40 dB would have a disproportionate impact on the generation capacity of the proposed Development. Furthermore, the generation capacity of the site is a relevant consideration. With a generation capacity of more than 50 MW, the proposed Development alone represents a development of national significance. At the time the ETSU-R-97 guidelines were produced, a wind farm site comprising more than a 100 turbines would have been required to achieve a similar generating capacity to that of the proposed Development alone, thus highlighting the scale of the scheme.

5.6.4 Considering the above factors, it is considered wholly appropriate to set the day-time noise limit at the upper end of the range of from 35 dB(A) to 40 dB(A).

5.6.5 Furthermore, the consent for the Arecleoch Windfarm stipulates 40 dB(A) to be the relevant fixed component of the limit at surrounding dwellings for the day-time period. This fixed limit value was relevant for the Arecleoch Windfarm on the premise of the significant energy generating capacity, combined with the relatively low number of dwellings in the surrounding area. The proposed Development forms an extension to the Arecleoch Windfarm, with both the Arecleoch Windfarm and the proposed Development being operated as a single windfarm by SPR. The Development will provide an increase to the already significant energy output of the Arecleoch Windfarm Windfarm, it therefore follows that 40 dB(A) is the appropriate fixed component of the day-time period limit for the combined total noise for the Arecleoch Windfarm and the Development when operating together. ACCON, on behalf of SAC, acknowledged that limits at the upper end of the range set out in ETSU-R-97 would be applicable in this case given the scale of wind energy development considered.

5.6.6 The assessment (shown in tabular form in Table 15 and Table 16) shows that the predictions for the combination of the Development and the existing Arecleoch turbines meet the ETSU-R-97 derived noise limits of Tables 5 and 6 under all wind speeds and at all locations, based on a lower day-time limit of 40 dB(A).

Table 15 - Difference between the ETSU-R-97 derived day time noise limits (Table 5) and the predicted $L_{A90,t}$ windfarm noise immission levels for the combination of the proposed Development and the existing Arecleoch turbines (Table 13) at each noise assessment location. values are based on a 40dB lower day time limit and negative values indicate the prediction is below the limit.

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	-15.5	-10.8	-8.4	-8.3	-8.2	-8.2	-8.2	-8.2	-8.2
Bellimore-on-Tig	-12.6	-7.9	-5.5	-5.4	-5.3	-5.3	-5.3	-5.3	-5.3
Bents Farm	-18.8	-14.7	-12.7	-13.1	-13.7	-14.9	-16.2	-17.7	-19.3
Brooklyn	-22.7	-18.1	-15.5	-15.1	-14.9	-15.7	-17.5	-19.2	-20.7
Cairnlea	-18.5	-13.9	-11.3	-10.8	-10.5	-10.5	-10.5	-10.5	-10.5
Chirmorrie	-14.1	-9.4	-7.0	-6.7	-6.5	-6.5	-6.5	-6.5	-6.5
Craigengells	-20.2	-16.1	-14.2	-14.6	-15.3	-16.4	-17.7	-19.2	-20.8
Dochroyle Cottage	-18.1	-13.4	-10.9	-10.6	-10.3	-10.3	-10.3	-10.3	-10.3
Dochroyle Farm	-18.0	-13.4	-10.9	-10.5	-10.3	-10.3	-10.3	-10.3	-10.3
Duisk Lodge	-21.2	-17.1	-15.1	-15.6	-16.2	-17.3	-18.7	-20.1	-21.8
East Altercannoch	-20.0	-15.4	-12.9	-12.5	-12.2	-13.4	-15.9	-18.1	-20.1
Farden	-16.2	-11.6	-9.0	-8.6	-8.2	-8.2	-8.2	-8.2	-8.2
Ferngate Cottage	-17.8	-13.3	-10.7	-10.3	-9.9	-9.9	-9.9	-9.9	-10.0
Glenour	-12.1	-7.5	-4.9	-4.5	-4.2	-4.2	-4.2	-4.2	-4.2
Gowlands	-21.7	-17.6	-15.7	-16.2	-17.1	-18.4	-19.8	-21.4	-23.0
Gowlands Terrace	-22.0	-17.8	-16.0	-16.5	-17.4	-18.7	-20.1	-21.7	-23.3
Kildonan Courtyard	-21.2	-17.0	-15.1	-15.5	-16.2	-17.4	-18.7	-20.1	-21.8
Kilrenzie	-11.9	-7.3	-4.7	-4.3	-4.0	-4.0	-4.0	-4.0	-4.0
Laggish	-19.3	-14.7	-12.1	-11.8	-11.5	-11.5	-13.3	-15.4	-17.2
Laigh Altercannoch	-22.5	-17.9	-15.4	-15.0	-14.7	-15.5	-17.3	-19.1	-20.5
Queensland Caravan Park	-20.0	-15.9	-14.0	-14.4	-15.0	-16.2	-17.5	-18.9	-20.6
Scaurhead	-21.2	-17.1	-15.2	-15.6	-16.2	-17.4	-18.7	-20.1	-21.8
The Craigs	-22.2	-17.6	-15.0	-14.6	-14.3	-15.1	-17.0	-18.7	-20.2
The Manse	-21.2	-17.0	-15.1	-15.5	-16.1	-17.3	-18.6	-20.1	-21.7
Ward of Cairnlea	-19.9	-15.3	-12.8	-12.4	-12.0	-12.0	-12.0	-12.0	-12.1
West Altercannoch	-19.8	-15.2	-12.6	-12.2	-11.9	-13.1	-15.6	-17.9	-19.8
Wheeb	-13.2	-8.6	-6.1	-5.8	-5.5	-5.5	-5.5	-5.5	-5.5
White Cairn	-19.1	-14.6	-12.0	-11.5	-11.2	-11.2	-11.2	-11.2	-13.2

Table 16 - Difference between the ETSU-R-97 derived night time noise limits (Table 6) and the predicted $L_{A90,t}$ windfarm noise immission levels for the combination of the proposed Development and the existing Arecleoch turbines (Table 13) at each noise assessment location. Negative values indicate the prediction is below the limit.

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	-18.5	-13.8	-11.4	-11.3	-11.2	-11.2	-11.2	-11.2	-11.2
Bellimore-on-Tig	-15.6	-10.9	-8.5	-8.4	-8.3	-8.3	-8.3	-8.3	-8.3
Bents Farm	-21.8	-17.2	-14.6	-14.2	-13.8	-13.8	-14.9	-16.3	-18.0
Brooklyn	-25.7	-21.1	-18.5	-18.1	-17.9	-17.9	-17.9	-18.8	-20.6
Cairnlea	-21.5	-16.9	-14.3	-13.8	-13.5	-13.5	-13.5	-13.5	-13.5
Chirmorrie	-17.1	-12.4	-10.0	-9.7	-9.5	-9.5	-9.5	-9.5	-9.5

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Craigengells	-23.2	-18.7	-16.1	-15.7	-15.3	-15.3	-16.4	-17.8	-19.5
Dochroyle Cottage	-21.1	-16.4	-13.9	-13.6	-13.3	-13.3	-13.3	-13.3	-13.3
Dochroyle Farm	-21.0	-16.4	-13.9	-13.5	-13.3	-13.3	-13.3	-13.3	-13.3
Duisk Lodge	-24.2	-19.6	-17.0	-16.6	-16.3	-16.3	-17.3	-18.8	-20.5
East Altercannoch	-23.0	-18.4	-15.9	-15.5	-15.2	-15.2	-15.2	-17.2	-19.2
Farden	-19.2	-14.6	-12.0	-11.6	-11.2	-11.2	-11.2	-11.2	-11.2
Ferngate Cottage	-20.8	-16.3	-13.7	-13.3	-12.9	-12.9	-12.9	-12.9	-12.9
Glenour	-15.1	-10.5	-7.9	-7.5	-7.2	-7.2	-7.2	-7.2	-7.2
Gowlands	-24.6	-20.0	-17.5	-17.1	-16.9	-17.8	-18.8	-20.0	-21.5
Gowlands Terrace	-24.9	-20.3	-17.7	-17.4	-17.2	-18.1	-19.1	-20.3	-21.8
Kildonan Courtyard	-24.2	-19.6	-17.0	-16.6	-16.3	-16.3	-17.3	-18.8	-20.5
Kilrenzie	-14.9	-10.3	-7.7	-7.3	-7.0	-7.0	-7.0	-7.0	-7.0
Laggish	-22.3	-17.7	-15.1	-14.8	-14.5	-14.5	-14.5	-14.5	-15.6
Laigh Altercannoch	-25.5	-20.9	-18.4	-18.0	-17.7	-17.7	-17.7	-18.6	-20.4
Queensland Caravan Park	-23.0	-18.4	-15.8	-15.4	-15.1	-15.1	-16.1	-17.6	-19.3
Scaurhead	-24.2	-19.6	-17.0	-16.6	-16.3	-16.3	-17.3	-18.8	-20.5
The Craigs	-25.2	-20.6	-18.0	-17.6	-17.3	-17.3	-17.3	-18.3	-20.0
The Manse	-24.2	-19.6	-17.0	-16.6	-16.2	-16.2	-17.3	-18.7	-20.4
Ward of Cairnlea	-22.9	-18.3	-15.8	-15.4	-15.0	-15.0	-15.0	-15.0	-15.0
West Altercannoch	-22.8	-18.2	-15.6	-15.2	-14.9	-14.9	-14.9	-16.9	-19.0
Wheeb	-16.2	-11.6	-9.1	-8.8	-8.5	-8.5	-8.5	-8.5	-8.5
White Cairn	-22.1	-17.6	-15.0	-14.5	-14.2	-14.2	-14.2	-14.2	-14.2

5.6.7 In addition, the assessment shown in tabular form in Table 17 and Table 18 shows that the predicted cumulative windfarm noise immission levels meet the ETSU-R-97 derived noise limits of Tables 5 and 6 under all wind speeds and at all locations, based on a lower day-time limit of 40 dB(A).

Table 17 - Difference between the ETSU-R-97 derived day time noise limits (Table 5) and the cumulative predicted $L_{A90,t}$ windfarm noise immission levels (Table 14) at each noise assessment location. values are based on a 40dB lower day time limit and negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	-15.0	-10.2	-7.7	-7.5	-7.4	-7.4	-7.4	-7.4	-7.4
Bellimore-on-Tig	-12.3	-7.5	-5.1	-4.9	-4.9	-4.9	-4.9	-4.9	-4.9
Bents Farm	-14.3	-9.8	-7.0	-7.1	-8.0	-9.1	-10.4	-11.9	-13.6
Brooklyn	-14.8	-9.8	-6.2	-5.5	-5.5	-6.3	-8.1	-9.8	-11.3
Cairnlea	-12.6	-7.6	-4.1	-3.4	-3.3	-3.3	-3.3	-3.3	-3.4
Craigengells	-14.4	-9.9	-7.0	-7.1	-8.0	-9.2	-10.5	-12.0	-13.6
Dochroyle Cottage	-11.3	-6.2	-3.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
Dochroyle Farm	-11.5	-6.3	-3.1	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9
Duisk Lodge	-14.2	-9.6	-6.7	-6.8	-7.7	-8.8	-10.2	-11.6	-13.3
East Altercannoch	-13.3	-8.2	-4.8	-4.2	-4.2	-5.4	-7.8	-10.1	-12.0
Farden	-14.0	-9.2	-6.0	-5.4	-5.3	-5.3	-5.3	-5.3	-5.3

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Ferngate Cottage	-12.4	-7.4	-4.0	-3.4	-3.3	-3.3	-3.3	-3.3	-3.4
Glenour	-11.6	-7.0	-4.3	-3.9	-3.6	-3.6	-3.6	-3.6	-3.6
Gowlands	-14.4	-9.8	-6.9	-7.1	-8.2	-9.5	-11.0	-12.5	-14.1
Gowlands Terrace	-14.5	-9.8	-6.9	-7.1	-8.2	-9.5	-11.0	-12.5	-14.2
Kildonan Courtyard	-14.5	-10.0	-7.1	-7.1	-8.1	-9.2	-10.5	-12.0	-13.7
Kilrenzie	-11.5	-6.9	-4.2	-3.8	-3.6	-3.6	-3.6	-3.6	-3.6
Laggish	-10.6	-5.4	-2.2	-2.1	-2.1	-2.1	-3.9	-6.0	-7.8
Laigh Altercannoch	-14.9	-9.9	-6.3	-5.6	-5.6	-6.4	-8.3	-10.0	-11.5
Queensland Caravan Park	-14.6	-10.0	-7.2	-7.3	-8.2	-9.3	-10.6	-12.1	-13.8
Scaurhead	-14.0	-9.5	-6.5	-6.6	-7.5	-8.7	-10.0	-11.4	-13.1
The Craigs	-14.2	-9.2	-5.6	-4.9	-4.8	-5.7	-7.5	-9.2	-10.7
The Manse	-14.1	-9.6	-6.6	-6.7	-7.6	-8.8	-10.1	-11.6	-13.2
Ward of Cairnlea	-13.4	-8.4	-4.9	-4.2	-4.2	-4.2	-4.2	-4.2	-4.3
West Altercannoch	-13.7	-8.7	-5.2	-4.6	-4.6	-5.8	-8.2	-10.5	-12.4
Wheeb	-12.7	-7.9	-5.3	-4.9	-4.7	-4.7	-4.7	-4.7	-4.7
White Cairn	-12.7	-7.7	-4.1	-3.4	-3.3	-3.3	-3.3	-3.3	-5.3

Table 18 - Difference between the ETSU-R-97 derived night time noise limits (Table 6) and the cumulative predicted $L_{A90,t}$ windfarm noise immission levels (Table 14) at each noise assessment location. Negative values indicate the immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	-18.0	-13.2	-10.7	-10.5	-10.4	-10.4	-10.4	-10.4	-10.4
Bellimore-on-Tig	-15.3	-10.5	-8.1	-7.9	-7.9	-7.9	-7.9	-7.9	-7.9
Bents Farm	-17.3	-12.3	-8.9	-8.2	-8.1	-8.1	-9.1	-10.6	-12.2
Brooklyn	-17.8	-12.8	-9.2	-8.5	-8.5	-8.5	-8.5	-9.4	-11.2
Cairnlea	-15.6	-10.6	-7.1	-6.4	-6.3	-6.3	-6.3	-6.3	-6.3
Craigengells	-17.4	-12.4	-8.9	-8.2	-8.1	-8.1	-9.2	-10.6	-12.3
Dochroyle Cottage	-14.3	-9.2	-6.0	-5.8	-5.8	-5.8	-5.8	-5.8	-5.8
Dochroyle Farm	-14.5	-9.3	-6.1	-5.9	-5.9	-5.9	-5.9	-5.9	-5.9
Duisk Lodge	-17.2	-12.2	-8.6	-7.9	-7.8	-7.8	-8.8	-10.3	-12.0
East Altercannoch	-16.3	-11.2	-7.8	-7.2	-7.2	-7.2	-7.2	-9.1	-11.2
Farden	-17.0	-12.2	-9.0	-8.4	-8.3	-8.3	-8.3	-8.3	-8.3
Ferngate Cottage	-15.4	-10.4	-7.0	-6.4	-6.3	-6.3	-6.3	-6.3	-6.3
Glenour	-14.6	-10.0	-7.3	-6.9	-6.6	-6.6	-6.6	-6.6	-6.6
Gowlands	-17.3	-12.2	-8.6	-7.9	-8.1	-8.9	-9.9	-11.2	-12.6
Gowlands Terrace	-17.3	-12.3	-8.7	-8.0	-8.1	-8.9	-10.0	-11.2	-12.7
Kildonan Courtyard	-17.5	-12.5	-8.9	-8.2	-8.2	-8.2	-9.2	-10.7	-12.3
Kilrenzie	-14.5	-9.9	-7.2	-6.8	-6.6	-6.6	-6.6	-6.6	-6.6
Laggish	-13.6	-8.4	-5.2	-5.1	-5.1	-5.1	-5.1	-5.1	-6.1
Laigh Altercannoch	-17.9	-12.9	-9.3	-8.6	-8.6	-8.6	-8.6	-9.6	-11.3
Queensland Caravan Park	-17.6	-12.6	-9.1	-8.4	-8.3	-8.3	-9.3	-10.8	-12.4
Scaurhead	-17.0	-12.0	-8.4	-7.7	-7.6	-7.6	-8.6	-10.1	-11.8
The Craigs	-17.2	-12.2	-8.6	-7.9	-7.8	-7.8	-7.8	-8.8	-10.5

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
The Manse	-17.1	-12.1	-8.5	-7.8	-7.7	-7.7	-8.8	-10.2	-11.9
Ward of Cairnlea	-16.4	-11.4	-7.9	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2
West Altercannoch	-16.7	-11.7	-8.2	-7.6	-7.6	-7.6	-7.6	-9.5	-11.6
Wheeb	-15.7	-10.9	-8.3	-7.9	-7.7	-7.7	-7.7	-7.7	-7.7
White Cairn	-15.7	-10.7	-7.1	-6.4	-6.3	-6.3	-6.3	-6.3	-6.3

5.6.8 The predictions of Table 13 do not exceed 30 dB L_{A90} at properties for which the consideration of cumulative noise levels is most relevant such as locations including Barrhill, Dochroyle Farm and Cottage, and Laggish. As the consented limits for other windfarms such as Kilgallioch and Mark Hill Windfarms is of a minimum of 40 dB L_{A90}, this means that the predicted contribution from the extended Arecleoch Windfarm is relatively negligible[1]. This also means that potential differences in the wind conditions experienced by the different windfarm sites considered would not affect the conclusions of this cumulative analysis.

5.6.9 As requested by SAC/ACCON, the property of Chirmorrie can be considered separately for the case of the Chirmorie Windfarm is not constructed and the property remains occupied. Table 17 presents predictions of noise levels (both individual and cumulative) and an assessment against the noise limits of Tables 5 and 6. This demonstrates that the predicted cumulative windfarm noise immission levels also meet the ETSU-R-97 derived noise limit at this property. Furthermore, the predictions at this property, which assume simultaneous downwind propagation, are particular conservative in this case as the property cannot be downwind of all turbines of Arecleoch and Kilgallioch Windfarms in particular. Therefore, even in this scenario, cumulative levels at this location are likely to be lower in practice.

Table 19 - Predicted L_{A90} windfarm noise immission levels and assessment at Chirmorrie as a function of standardised wind speed

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Arecleoch Windfarm + Extension	25.9	30.6	33.0	33.3	33.5	33.5	33.5	33.5	33.5
Kilgallioch Windfarm	30.1	35.4	38.6	38.6	38.6	38.6	38.6	38.6	38.6
Mark Hill Windfarm	14.4	19.5	23.4	24.3	24.3	24.3	24.3	24.3	24.3
Cumulative without Chirmorie	31.6	36.7	39.8	39.9	39.9	39.9	39.9	39.9	39.9
Day-time limit	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Day-time limit margin	-8.4	-3.3	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Night-time limit	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Night-time limit margin	-11.4	-6.3	-3.2	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1

5.6.10 It is finally concluded that predicted cumulative noise immission levels from the proposed Development when operating with the operational Arecleoch, Kilgallioch and Mark Hill Windfarms, as

[1] The IOA GPG suggests that cumulative noise effects need not be considered where differences between existing and proposed wind farm noise levels are 10 dB or more. The addition of a noise source 10 dB(A) below that of another theoretically adds 0.4 dB to the total but is not considered to require assessment according to the IOA GPG.

well as the consented Chirmorie Windfarm are compliant with the ETSU-R-97 criteria at all locations and all wind speeds.

5.6.11 The Arecleoch Windfarm and the proposed Development will effectively be operated as a single windfarm by SPR, and it would therefore be appropriate to apply a single noise limit to the totality of Arecleoch Windfarm and the proposed Development when operated together. Tables 20 and 21 set out specific day-time and night-time limits which were determined to apply to the combination of the Arecleoch Windfarm and the proposed Development.

5.6.12 These specific limits were determined at representative locations: being either one of the survey locations (Table 2 and 3 above) or one for which the predictions of Table 13 were close to or above 30dB L_{A90}. The specific noise limits of Tables 20 and 21 were determined such that, when added to the predicted total combined contribution of the Kilgallioch, Mark Hill and Chirmorie Windfarms, the resulting cumulative noise levels would remain below the total ETSU-R-97 noise limits of Tables 5 and 6. Please note that this was generally determined on the basis of simultaneous downwind propagation from all turbines, which represents a conservative assumption for most of the properties considered as discussed above.

5.6.13 For the Chirmorrie property (should it be retained), this assumption is particularly unrealistic as the Kilgallioch and Arecleoch (and proposed Extension) windfarms are located in opposite directions from the property. ore detailed directional predictions are set out in Annex G, considering likely directional propagation effects on a conservative basis: the method used for these predictions is consistent with guidance in the IOA GPG. The limits of Tables 20 and 21 are defined at the Chirmorrie location in conditions of downwind propagation for the Arecleoch Windfarm and the proposed Development.

5.6.14 Satisfactory control of cumulative noise immission levels would therefore be achieved through enforcement of the individual consent limits for each of the different windfarms.

Table 20 – specific day time noise limits (L_{A90}) applicable to the combination of the Arecleoch Windfarm and the proposed Development

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9
Bellimore-on-Tig	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9
Brooklyn	38.7	38.7	38.7	38.7	38.7	39.6	41.4	43.1	44.6
Chirmorrie*	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2
Dochroyle Cottage	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Dochroyle Farm	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6	37.6
East Altercannoch	38.3	38.3	38.3	38.3	38.3	39.5	42.0	44.2	46.2
Farden	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3
Glenour	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8
Gowlands Terrace	39.3	39.7	40.4	41.3	42.4	43.8	45.2	46.8	48.4
Kilrenzie	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8
Laggish	36.5	36.5	36.5	36.5	36.5	36.5	38.3	40.5	42.3
Queensland Caravan Park	39.3	39.7	40.4	41.2	42.2	43.3	44.6	46.1	47.8
Ward of Cairnlea	38.3	38.3	38.3	38.3	38.3	38.3	38.3	38.3	38.4
West Altercannoch	38.5	38.5	38.5	38.5	38.5	39.7	42.2	44.5	46.4
Wheeb	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8	39.8
White Cairn	37.9	37.9	37.9	37.9	37.9	37.9	37.9	37.9	39.9

Table 21 - specific night time noise limits (L_{A90}) applicable to the combination of the Arecleoch Windfarm and the proposed Development

Property	Standardised 10 m Wind Speed (m/s)								
	4	5	6	7	8	9	10	11	12
Balkissock	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9
Bellimore-on-Tig	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9
Brooklyn	41.7	41.7	41.7	41.7	41.7	41.7	41.7	42.7	44.4
Chirmorrie*	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2
Dochroyle Cottage	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5	40.5
Dochroyle Farm	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6
East Altercannoch	41.3	41.3	41.3	41.3	41.3	41.3	41.3	43.3	45.3
Farden	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3
Glenour	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8
Gowlands Terrace	42.1	42.1	42.1	42.1	42.3	43.1	44.2	45.4	46.9
Kilrenzie	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8
Laggish	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	40.6
Queensland Caravan Park	42.3	42.3	42.3	42.3	42.3	42.3	43.3	44.8	46.4
Ward of Cairnlea	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3
West Altercannoch	41.5	41.5	41.5	41.5	41.5	41.5	41.5	43.5	45.6
Wheeb	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8	42.8
White Cairn	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9	40.9

**N.B. if the Chirmorie Windfarm is constructed, the Chirmorrie property would become unoccupied and a noise limit would not apply to that property. Otherwise, this limit will apply over the range of 235 to 45 degrees from North, corresponding to broadly downwind conditions for the Arecleoch Windfarm and the proposed Development.*

5.7 Low Frequency Noise, Vibration and Amplitude Modulation

5.7.1 Low frequency noise and vibration resulting from the operation of windfarms are issues that have been attracting a certain amount of attention over recent years. Consequently, Annex A includes a detailed discussion of these topics. In summary of the information provided therein, the current recommendation is that ETSU-R-97 should continue to be used for the assessment and rating of operational noise from windfarms.

5.7.2 Annex A also discusses the most recently published research on the subject of wind turbine blade swish Amplitude Modulation (or AM). As a consequence of the combined results of this research, and in particular the development by the IOA of an objective technique for identifying and quantifying AM noise, as well as a review of the subjective response to AM noise by a Government-commissioned research group, a penalty-type approach to account for instances of increased AM outside what is expected from 'normal' blade swish has been proposed. Some uncertainty remains at this stage over the application of such a penalty and this will be subject to a period of testing and review over the next few years.

5.8 Substation and battery storage

5.8.1 The main noise sources associated with the substation are likely to be the power transformers and the cooling fans. Operational noise associated with any ancillary services such as battery energy storage facility would arise from ventilation/air conditioning systems, modular inverters and lower-voltage transformers and higher-voltage transformers associated with grid connection (were this not to be shared with the main windfarm substation).

5.8.2 Given the large separation distances of around 2 kilometres or more between the substation and battery storage area and the nearest residential properties, experience of similar installations and professional judgement, the associated levels of operational noise would be negligible and not significant. Therefore, no specific mitigation is required in this instance.

5.9 Evaluation of Effects

Table 22 – Summary of effects

Potential Effect	Evaluation of Effect
Construction Noise	Noise levels have been predicted using the methodology set out in BS 5228. Based on assessment criteria derived and supported by a range of noise policy and guidance, overall construction noise levels are considered to represent a negligible to slight effect, and therefore considered not significant in EIA terms.
Operational Noise	Noise criteria have been established in accordance with ETSU-R-97. It has also been shown that these criteria are achievable with a commercially available turbine suitable for the Site. The basis of the ETSU-R-97 method is to define acceptable noise limits thought to offer reasonable protection to residents in areas around windfarm developments. At some locations under some wind conditions and for a certain proportion of the time, the windfarm noise may be audible; however, operational noise immission levels are acceptable in terms of the guidance commended by planning policy for the assessment of windfarm noise, and therefore considered not significant in EIA terms.

6. Mitigation, Offsetting and Enhancement Measures

6.1 Proposed Construction Noise Mitigation Measures

6.1.1 To reduce the potential effects of construction noise, the following types of mitigation measures are proposed:

- Those activities that may give rise to audible noise at the surrounding properties and heavy goods vehicle deliveries to the Site would be limited to the 07:00 to 19:00 Monday to Friday and 07:00 to 16:00 on Saturdays and Sundays. Turbine deliveries would only take place outside these times with the prior consent of the Council and the Police. Those activities that are unlikely to give rise to noise audible at the Site boundary will continue outside of the stated hours.
- All construction activities shall adhere to good practice as set out in BS 5228.
- All equipment will be maintained in good working order and any associated noise attenuation such as engine casing and exhaust silencers shall remain fitted at all times.
- Where flexibility exists, activities will be separated from residential neighbours by the maximum possible distances.
- A site management regime will be developed to control the movement of vehicles to and from the proposed Development site.
- Construction plant capable of generating significant noise and vibration levels will be operated in a manner to restrict the duration of the higher magnitude levels.

6.1.2 If blasting is to be employed at some of the borrow pits located less than 2 km away from noise-sensitive locations, the potential noise and vibration effects of blasting operations will be reduced according to the guidance set out in the relevant British Standards and PAN50 annex D and discussed below:

- Blasting should take place under strictly controlled conditions with the agreement of the relevant authorities, at regular times within the working week, that is, Mondays to Fridays, between the hours of 10.00 and 16.00. Blasting on Saturday mornings should be a matter for negotiation between the contractor and SAC;
- Vibration levels at the nearest sensitive properties are best controlled through on-site testing processes carried out in consultation with the Local Authorities. This site testing based process would include the use of progressively increased minor charges to gauge ground conditions both in terms of propagation characteristics and the level of charge needed to release the requisite material. The use of onsite monitoring at neighbouring sensitive locations during the course of this preliminary testing can then be used to define upper final charge values that will ensure vibration levels remain within the criteria set out previously, as described in BS 5228-2 and BS 6472-2 2008;
- Blasting operations shall adhere to good practice as set out in BS 5228-2, and in PAN50, Annex D, Paragraph 95 in order to control air overpressure.
- A scheme will be submitted to SAC, for approval of blasting details, which will outline the mitigation measures to be adopted.

6.2 Proposed Operational Noise Mitigation Measures

6.2.1 The selection of the final turbine to be installed at the Site would be made on the basis of enabling the relevant noise limits (Tables 20 and 21) to be achieved at the surrounding properties.

7. Monitoring

7.1.1 It is proposed that if planning consent is granted for the proposed Development, conditions attached to the planning consent should include the requirement that, in the event of a noise complaint, noise levels resulting from the operation of the windfarm are measured in order to demonstrate compliance with the conditioned noise limits. Such monitoring should be done in full accordance with ETSU-R-97 and current good practice and include penalties for characteristics of the noise (if present).

7.1.2 As discussed above, noise limits included in the consent should apply to the totality of the Arecleoch Windfarm and the proposed Development when operated together. The noise limits of Tables 20 and 21 above should be referenced as they were derived as specific noise limits which will maintain the conclusions of the above cumulative noise assessment.

7.1.3 In some cases, predictions for the combination of the Arecleoch Windfarm and the proposed Development (Table 13) are below measured background noise levels in the area, with some of the locations considered located more than 2 km from the existing or proposed turbines. In such cases, a measurement survey undertaken to assess compliance with the specific noise limits derived may therefore involve a lengthy survey and onerous procedures for the operator. It is therefore proposed that the conditions attached to the planning consent require in the first instance determining if measured ambient noise levels exceed the total ETSU-R-97 noise limits set out in Tables 5 and 6. Only if this is the case should the specific contribution of the Arecleoch Windfarm and the proposed Development, operating together, be assessed against the specific noise limits of Tables 20 and 21 above. The details of this procedure could be agreed with SAC in a process secured through planning conditions for the proposed Development.

8. Summary of Key Findings and Conclusions

8.1.1 This report has presented an assessment of the effects of construction and operational noise from the proposed Development on the residents of nearby dwellings.

8.1.2 A number of residential properties lying around the windfarm have been selected as being representative of the closest located properties to the windfarm. The minimum separation distance between the nearest turbine and the closest located residential property is approximately 1100 metres, but with most properties located 2 or 3 km away. Noise assessments have been undertaken at these properties by comparing predicted construction and operational noise levels with relevant assessment criteria. In the case of construction noise, relevant assessment criteria are in the form of absolute limit values derived from a range of environmental noise guidance. In relation to operational noise, the limits have been derived from the new background noise levels measurements at 5 surrounding properties, as well as reference to previously measured background noise levels.

8.1.3 The construction noise assessment has determined that associated levels are expected to be audible at various times throughout the construction programme, but remain with acceptable limits such that their temporary effects are considered negligible to slight.

8.1.4 Operational noise from the windfarm has been assessed in accordance with the methodology set out in the 1996 DTI Report ETSU-R-97, 'The Assessment and Rating of Noise from Wind Farms'. This document provides a robust basis for assessing the operational noise of a windfarm as recommended in Scottish Planning Policy.

8.1.5 Applying the ETSU-R-97 derived noise limits at the assessment locations it has been demonstrated that both the day-time and night-time noise criterion limits can be satisfied at all properties across all wind speeds. This included the cumulative effect of the operational Arecleoch, Kilgallioch and Mark Hill Windfarms, as well as the consented Chirmorie Windfarm. The assessment of the proposed Development has been based on the use of the manufacturer's warranted sound power data for the Vestas V150 5.6MW wind turbine which is typical of the type and size of turbine which may be considered for this site, and assuming worst case downwind propagation.

8.1.6 In summary, the overall levels of construction noise are considered to represent a slight effect, and therefore considered not significant in EIA terms. At some locations under some wind conditions and for a certain proportion of the time, the windfarm noise may be audible; however, operational noise immission levels are acceptable in terms of the guidance commended by planning policy for the assessment of windfarm noise, and therefore considered not significant in EIA terms.

9. References

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Annex A - General Approach to Noise Assessment & Glossary

A.1 Some sound, such as speech or music, is desirable. However, desirable sound can turn into unwanted noise when it interferes with a desired activity or when it is perceived as inappropriate in a particular environment.

A.2 When assessing the effects of sound on humans there are two equally important components that must both be considered: the physical sound itself, and the psychological response of people to that sound. It is this psychological component which results in those exposed differentiating between desirable sound and unwanted noise. Any assessment of the effects of sound relies on a basic appreciation of both these components. This Annex provides an overview of these topics. A glossary of acoustic terminology is included at the end of this Annex.

A.3 The assessment of environmental noise can be best understood by considering physical sound levels separately from the likely effects that these physical sound levels have on people, and on the environment in general.

A.4 Physical sound is a vibration of air molecules that propagates away from the source. As acoustic energy (carried by the vibration back and forth of the air molecules) travels away from the source of the acoustic disturbance it creates fluctuating positive and negative acoustic pressures in the atmosphere above and below the standing atmospheric pressure. For most types of sound normally encountered in the environment these acoustic pressures are extremely small compared to the atmospheric pressure. When acoustic pressure acts on any solid object it causes microscopic deflections in the surface. For most types of sound normally encountered in the environment these deflections are so small they cannot physically damage the material. It is only for the very highest energy sounds, such as those experienced close to a jet engine for example, that any risk of physical damage exists. For these reasons, most sound is essentially neutral and has no cumulative damaging physical effect on the environment. The effects of environmental sound are therefore limited to its effects on people or animals.

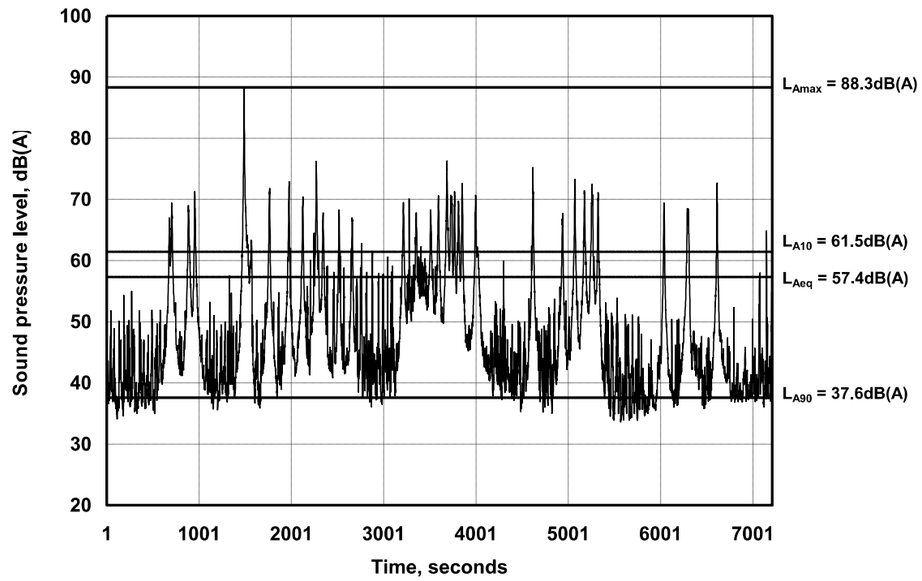
A.5 Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

Indicators of Physical Sound Levels

A.6 Physical sound is measured using a sound level meter. A sound level meter comprises two basic elements: a microphone which responds in sympathy with the acoustic pressure fluctuations and produces an electrical signal that is directly related to the incident pressure fluctuations, and a meter which converts the electrical signal generated by the microphone into a decibel reading. Figure A1 shows an example of the time history of the decibel readout from a sound level meter located approximately 50 metres from a road. The plot covers a total time period of approximately 2 hours. The peaks in the sound pressure level trace correspond to the passage of individual vehicles past the measurement location.

A.7 Assigning a single value to the time varying sound pressure level presented in Figure A1 is clearly not straightforward, as the sound pressure level varies by over 50 dB with time. To overcome this, the measurement characteristics of sound level meters can be varied to emphasise different features of the sound that are thought to be most relevant to the effect under consideration.

Figure A1 Sample plot of the sound pressure level measured close to a road over a period of approximately two hours.



Objective measures of noise

A.8 The primary purpose of measuring environmental noise is to assess its effects on people. Consequently, any sound measuring device employed for the task should provide a simple readout that relates the objectively measured sound to human subjective response. To achieve this, the instrument must, as a minimum, be capable of measuring sound over the full range detectable by the human ear.

A.9 Perceived sound arises from the response of the ear to sound waves travelling through the air. Sound waves comprise air molecules oscillating in a regular and ordered manner about their equilibrium position. The speed of the oscillations determines the frequency, or pitch, of the sound, whilst the amplitude of oscillations governs the loudness of the sound. A healthy human ear is capable of detecting sounds at all frequencies from around 20 Hz to 20 kHz over an amplitude range of approximately 1,000,000 to 1. Even relatively modest sound level meters are capable of detecting sounds over this range of amplitudes and frequencies, although the accuracy limits of sound level meters vary depending on the quality of the unit. When undertaking measurements of wind turbine noise, as with all other noise measurements, it is important to select a measurement system that possesses the relevant accuracy tolerances and is calibrated to a matching standard.

A.10 Whilst measurement systems exist that are capable of detecting the range of sounds detected by the human ear, the complexities of human response to sound make the derivation of a likely subjective response from a simple objective measure a non-trivial problem. Not only does human response to sound vary from person to person, but it can also depend as much on the activity and state of mind of an individual at the time of the assessment, and on the 'character' of the sound, as it can on the actual level of the sound. In practice, a complete range of responses to any given sound may be observed. Thus, any objective measure of noise can, at best, be used to infer the average subjective response over a sample population.

Sound Levels and Decibels

A.11 Because of the broad amplitude range covered by the human ear, it is usual to quantify the magnitude of sound using the decibel scale. When the amplitude of sound pressure is expressed using decibels (dB) the resultant quantity is termed the sound pressure level. Sound pressure levels are denoted by a capital 'L', as in L dB. The conversion of sound pressure from the physical quantity of Newton per square metre, or Nm-2, to sound pressure level in dB reduces the range from 0 dB at the threshold of hearing to 120 dB at the onset of pain. Both of these values are derived with respect to the hearing of the average healthy young person.

A.12 Being represented on a logarithmic amplitude scale, the addition and subtraction of decibel quantities does not follow the normal rules of linear arithmetic. For example, two equal sources acting together produce a sound level 3 dB higher than either source acting individually, so 40 dB + 40 dB = 43 dB and 50 dB + 50 dB = 53 dB. Ten equal sound sources acting together will be 10 dB louder than each source operating in isolation. Also, if one of a pair of sources is at least 10 dB quieter than the other, then it will contribute negligibly to the combined noise level. So, for example, 40 dB + 50 dB = 50 dB.

A.13 An increase in sound pressure level of 3 dB is commonly accepted as the smallest change of any subjective significance. An increase of 10 dB is often claimed to result in a perceived doubling in loudness, although the basis for this claim is not well founded. An increase of 3 dB is equivalent to a doubling in sound energy, which is the same as doubling the number of similar sources. An increase of 10 dB is equivalent to increasing the number of similar sources tenfold, whilst an increase of 20 dB requires a hundredfold increase in the number of similar sources and an increase of 30 dB requires a thousand times increase in the number of sources.

Frequency Selectivity of Human Hearing and A-weighting

A.14 Whilst the hearing of a healthy young individual may detect sounds over a frequency range extending from less than 20 Hz to greater than 20 kHz, the ear is not equally sensitive at all frequencies. Human hearing is most sensitive to sounds containing frequency components lying within the range of predominant speech frequencies from around 500 Hz to 4000 Hz. Therefore, when relating an objectively measured sound pressure level to subjective loudness, the frequency content of the sound must be accounted for.

A.15 When measuring sound with the aim of assessing subjective response, the frequency selectivity of human hearing is accounted for by down-weighting the contributions of lower and higher frequency sounds to reduce their influence on the overall reading. This is achieved by using an 'A'-weighting filter. Over the years, the A-weighting has become internationally standardised and is now incorporated into the majority of environmental noise standards and regulations in use around the world to best replicate the subjective response of the human ear. A-weighting filters are also implemented as standard on virtually all sound measurement systems.

A.16 Sound pressure levels measured with the A-weighting filter applied are referred to as 'A weighted' sound pressure levels. Results from such measurements are denoted with a subscripted capital A after the 'L' level designation, as in 45 dB LA, or alternatively using a bracketed 'A' after the 'dB' decibel designation, as in 45 dB(A).

Temporal Variation of Noise and Noise Indices

A.17 The simple A-weighted sound pressure level provides a snapshot of the sound environment at any given moment in time. However, as is adequately demonstrated by Figure A1, this instantaneous sound level can vary significantly over even short periods of time. A single number indicator is therefore required that best quantifies subjective response to time varying environmental noise, such as that shown in Figure A1. The question thus arises as to how temporal variations in level should be accounted for. This is most often achieved in practice by selecting a representative time period and

calculating either the average noise level over that time period or, alternatively, the noise level exceeded for a stated proportion of that time period, as discussed below.

Equivalent Continuous Sound Level, $L_{Aeq,T}$

A.18 The equivalent continuous sound level, or $L_{Aeq,T}$ averages out any fluctuations in level over time. It is formally defined as the level of a steady sound which, in a stated time period 'T' and at a given location, has the same sound energy as the time varying sound. The $L_{Aeq,T}$ is a useful 'general' noise index that has been found to correlate well with subjective response to most types of environmental noise.

A.19 The equivalent continuous sound level is expressed $L_{Aeq,T}$ in dB, where the A–weighting is denoted by the subscripted 'A', the use of the equivalent continuous index is denoted by the subscripted 'eq', and the subscripted 'T' refers to the time period over which the averaging is performed. So, for example, 45 dB $L_{Aeq,1hr}$ indicates that A-weighted equivalent continuous noise level measured over a one hour period was 45 dB.

A.20 The disadvantage of the equivalent continuous sound level is that it provides no information as to the temporal variation of the sound. For example, an $L_{Aeq,1hr}$ of 60 dB could result from a sound pressure level of 60 dB(A) continuously present over the whole hour's measurement period, or it could arise from a single event of 96 dB(A) lasting for just 1 second superimposed on a continuous level of 30 dB(A) which exists for the remaining 59 minutes and 59 seconds of the hour long period. Clearly, the subjective effect of these two apparently identical situations (if one were to rely solely on the L_{Aeq} index) could be quite different.

A.21 The aforementioned feature can produce problems where the general ambient noise level is relatively low. In such cases the $L_{Aeq,T}$ can be easily 'corrupted' by individual noisy events. Examples of noisy events that often corrupt $L_{Aeq,T}$ noise measurements in situations of low ambient noise levels include birdsong or a dog bark local to a noise monitoring point, or an occasional overflying aircraft or a sudden gust of wind. This potential downside to the use of $L_{Aeq,T}$ as a general measurement index is of particular relevance to the assessment of ambient noise in quiet environments, such as those typically found in rural areas where windfarms are developed.

A.22 Despite these shortcomings in low noise environments, the $L_{Aeq,T}$ index is increasingly becoming adopted as the unit of choice for both UK and European guidance and legislation, although this choice is often as much for reasons of commonality between standards as it is for overriding technical arguments. In the Government's current planning policy guidance notes the $L_{Aeq,T}$ noise level is the index of choice for the general assessment of environmental noise. This assessment is undertaken separately for day time ($L_{Aeq,16hr}$ 07:00 to 23:00) and night time ($L_{Aeq,8hr}$ 23:00 to 07:00) periods. However, it is often the case for quiet environments, or for non-steady noise environments, that more information than can be gleaned from the $L_{Aeq,T}$ index may be required to fully assess potential noise effects.

Maximum, L_{Amax}, and percentile exceeded sound level, $L_{An,T}$

A.23 Figure A1 shows, superimposed on the time varying sound pressure level trace and in addition to the $L_{Aeq,T}$ noise level, examples of three well established measurement indices that are commonly used in the assessment of environmental noise impacts. These are the maximum sound pressure level, L_{Amax}, the 90 percentile sound pressure level, $L_{A90,T}$ and the ten percentile sound pressure level, $L_{A10,T}$.

A.24 The $L_{Amax,F}$ readings is suited to indicating the physical magnitude of the single individual sound event that reaches the maximum level over the measurement period, but it gives no indication of the number of individual events of a similar level that may have occurred over the time period.

A.25 Unlike the $L_{Aeq,T}$ index and the $L_{Amax,F}$ indices, percentile exceeded sound levels, percentage exceeded sound levels provide some insight into the temporal distribution of sound level throughout the averaging period. Percentage exceeded sound levels are defined as the sound level exceeded by a

fluctuating sound level for n% of the time over a specified time period, T. They are denoted by $L_{An,T}$ in dB, where 'n' can take any value between 0% and 100%.

A.26 The $L_{A10,T}$ and $L_{A90,T}$ indices are the most commonly encountered percentile noise indices used in the UK.

A.27 The 10%'ile index, or $L_{A10,T}$ provides a measure of the sound pressure level that is exceeded for 10% of the total measurement period. It therefore represents the typical upper level of sound associated with specific events, such as the passage of vehicles past the measurement point. It is the traditional index adopted for road traffic noise. This index is useful because traffic noise is not usually constant, but rather it fluctuates with time as vehicles drive past the receptor location. The $L_{A10,T}$ therefore characterises the typical level of peaks in the noise as vehicles drive past, rather than the lulls in noise between the vehicles.

A.28 The $L_{A90,T}$ noise index is the noise level exceeded for 90% of the time period, T. It provides an estimate of the level of continuous background noise, in effect performing the inverse task of the $L_{A10,T}$ index by detecting the lulls between peaks in the noise. It is for this reason that the $L_{A90,T}$ noise index is the favoured unit of measurement for windfarm noise where, for the reasons discussed above, the generally low $L_{Aeq,T}$ noise levels are easily corrupted by intermittent sounds such as those produced by livestock, agricultural vehicles or the occasional passing vehicle on local roads. The $L_{A90,T}$ noise level represents the typical lower level of sound that may be reasonably expected to be present for the majority (90%) of the time in any given environment. This is usually referred to as the 'background' noise level.

Temporal Variations Outside the Noise Index Averaging Periods, 'T'

A.29 Averaging noise levels over the time period 'T' of the $L_{Aeq,T}$ and $L_{An,T}$ noise indices can successfully account for variations in noise over the time period, T. Some variations, however, exhibit trends over longer periods. At larger distances from noise sources meteorological factors can significantly affect received noise levels. At a few hundred metres from a constant level source of noise the potential variation in noise levels may be greater than 15 dB(A). To account for this variability consideration must be taken of meteorological conditions, particularly wind direction, when measurements and predictions are undertaken. As a general rule, when compared with the received noise level under neutral wind conditions, wind blowing from the source to the receiver can slightly enhance the noise level at the receiver (typically by no more than 3 dB(A)), but wind blowing from the receiver to the source can very significantly reduce the noise level at the receiver (typically by 15 dB(A) or more).

A.30 A similar effect occurs under conditions of temperature inversion, such as may exist after sunset when radiative cooling from the ground lowers the temperature of the air lying at low level more quickly than the air at higher levels, by loss of temperature through convective effects. This results in the air temperature increasing with increasing height above the ground. Depending on the source to receiver distance relative to the heights of the source and receiver, this situation can lead to sound waves becoming 'trapped' in the layer of air lying closest to the ground. The consequence is that noise levels at receptor locations can increase relative to those experienced under conditions of a neutral temperature gradient or a temperature lapse. The maximum increases compared to neutral conditions are similar to those experienced under downwind conditions of no more than around 3 dB(A). It is also worth noting that temperature lapse conditions, which is the more usual situation where temperature decreases with increasing height, can result in reductions in noise level at receptor locations by 15 dB(A) or more compared with the neutral conditions. The similarity between the magnitude of potential variations in noise levels for wind induced and temperature induced effects is not surprising, as the physical mechanisms behind the variations in level are the same for both situations: both variations result from changes in the speed of sound as a function of height above local ground level.

A.31 Temperature inversions on very still days can also affect noise propagation over much larger distances of several kilometres. These effects can produce higher than expected noise levels even at these very

large distances from the source. A classic example that many people have experienced is the distant, usually inaudible, railway train that suddenly sounds like it is passing within a few hundred metres of a dwelling. However, these situations must generally be considered as rare exceptions to the usually encountered range of noise propagation conditions, especially in the case of windfarm noise as they rely on calm wind conditions under which wind turbines do not operate.

Effects of Sound on People

A.32 Except at very high peak acoustic pressures, the energy levels in most environmental sounds are too low to cause any physical disruption in any part of the body, just as they are too low to cause any direct physical damage to the environment. The main effects of environmental sound on people are therefore limited to possible interference with specific activities or to some kind of annoyance response. Some researchers have claimed statistical associations between environmental noise and various long term health effects such as clinical hypertension or mental health problems, although there is no consensus on possible causative mechanisms. Evidence in support of health effects other than annoyance and some indicators of sleep disturbance is weak. However, the theory that psychological stress caused by annoyance might contribute to adverse health effects in otherwise susceptible individuals seems plausible. Health effects in the 'more usual' definition of physiological health therefore remain as a theoretical possibility which has neither been proved nor disproved. However, the World Health Organisation (WHO) defines health in the wider context of:

> *'a state of complete physical, mental and social well-being and not merely the absence of infirmity'.*

And within this wider context potential health effects of environmental noise are summarised by the World Health Organisation as:

- interference with speech communications;
- sleep disturbance;
- disturbance of concentration;
- annoyance; and
- social and economic effects.

Speech Interference

A.33 The instantaneous masking effects of unwanted noise on speech communication can be predicted with some accuracy by using specialist methods of calculation, but the overall effect of a small amount of speech interference on everyday life is harder to judge. The significance of speech masking depends on the context in which it occurs. For example, isolated noise events could interfere with telephone conversations by masking out particular words or parts of words but, because of the high redundancy in normal speech, the masking of individual words can often have no significant effect on the intelligibility of the overall message. Notwithstanding the above, noise levels from windfarms at even the closest located dwellings in otherwise quiet environments are usually no more than around 30 dB(A) indoors, even with windows open. This internal noise level is 5 dB(A) below the 35 dB(A) suggested by the World Health Organisation as the lowest potential cut-on level for issues relating to speech intelligibility.

Sleep Disturbance

A.34 Although sleep seems to be a fundamental requirement for humans, the most significant effect of sleep loss seems to be increased sleepiness the next day. Sleep normally follows a regular cyclic pattern from awake through light sleep to deep sleep and back, this cycle repeating several times during the night at around 90 minute intervals. Most people wake for short periods several times every night as part of the normal sleep cycle without necessarily being aware of this the next day. REM, or rapid eye

movement, sleep is associated with dreaming and occurs several times each night during the lighter sleep stages.

A.35 Electroencephalography (EEG) and similar techniques can be used to detect transient physiological responses to noise at night. Transient responses can be detected by short bursts of activity in the recorded waveforms which often settle back down to the same pattern as immediately before the event. Sometimes a transient response will be the precursor of a definite lightening of sleep, or even of an awakening, but often no discernible physical event happens at all.

A.36 These results suggest that at least parts of the auditory system remain fully operational even while the listener is asleep. The main purpose of this seems to be to arouse the listener in case of danger or in case some particular action is required which cannot easily be accomplished whilst remaining asleep. On the other hand, the system appears to be designed to filter out familiar sounds which experience suggests do not require any action. A very loud sound is likely to overcome the filtering mechanism and wake the listener, while intermediate and quieter sounds might only wake a listener who has a particular focus on those specific sounds. There is no evidence that the transient physiological responses to noise whilst asleep are anything other than normal. There is also considerable anecdotal evidence that people habituate to familiar noise at night, although some of the research evidence on this point is contradictory.

A.37 There is no consensus on how much sleep disturbance is significant. Some authorities take a precautionary approach, under which any kind of physiological response to noise is considered important, irrespective of whether there are any next day effects or not. Other studies suggest that transient physiological responses to unfamiliar stimuli at night are merely an indication of normal function and do not need to be considered as adverse effects unless they contribute to significant next-day effects. Recent World Health Organisation guidelines based mainly on laboratory studies suggest indoor limit values of 30 dB L_{Aeq} and 45 dB L_{Afmax} to avoid sleep disturbance, while other studies carried out in-situ, where habituation to the noise in question may have occurred, have found that much higher levels can be tolerated without any noticeable ill-effects.

Noise Annoyance

A.38 Noise annoyance describes the degree of 'unwantedness' of a particular sound in a particular situation. People's subjective response to noise can vary from not being bothered at all, through a state of becoming aware of the noise, right through to the point of becoming annoyed by the noise when it reaches a sufficiently high level. There is no statutory definition of noise annoyance.

A.39 Numerous noise annoyance surveys carried out over the last three decades have attempted to establish engineering relationships between the amount of noise measured objectively using sound level meters and the amount of community annoyance determined from questionnaires. The chief outcome of 'reported annoyance' has been measured using a very large range of different ideas. Both the wording of any questionnaire used and the context in which the question is put, and the manner in which it is therefore interpreted by respondents, can be very important. Some researchers are developing standardised questionnaire formats to encourage greater comparability between different studies, but this does not address the possibility of different contextual effects.

A.40 Notwithstanding these problems, there is a general consensus that average reported annoyance increases with aggregate noise level in long term static situations. However, there has been comparatively little research and consequently no real agreement on the effects of change. Some studies have found that even small changes in noise level can have unexpectedly large consequences on reported annoyance, while others have found the opposite. The most likely explanation for these apparent discrepancies is that underlying or true annoyance depends on many non-acoustic factors in addition to noise level alone, and that the extent to which reported annoyance actually represents underlying annoyance can be highly dependent on context. As a consequence, attempts to find a common relationship across all noise sources and listening situations have generally floundered. This

task has been complicated by the great range of individual sensitivities to noise observed in the surveys, often affected as much by attitude as by noise level.

A.41 Whether or not an exposed individual has a personal interest in a given sound often has a significant bearing on their acceptance of it. For example, if recipients gain benefit from an association with the sound producer, or if they accept that the sound is necessary and largely unavoidable, then they are likely to be more tolerant of it. This is often the case even if they don't necessarily consider it desirable. A good example of this is road traffic noise which is the dominant noise heard by over 90% of the population but results in relatively few complaints.

A.42 Notwithstanding the fact that attitudes may be as important as overall levels in determining the acceptance of a particular noise, there still remains a need to objectively quantify any changes in noise level. Whilst it may not be possible to attribute a particular degree of annoyance to a given noise level, an objective measure of noise that bears some relationship to annoyance is still useful. This objective measure enables an assessment of the effect of changes to be assessed on the basis that any reduction in overall noise level must be beneficial. Possible noise mitigation measures form a central consideration of any noise assessment, so an appropriate methodology must be adopted for assessing the effectiveness of any noise mitigation measures adopted.

A.43 When assessing the potential effects of any new source of noise, it is common practice to compare the A-weighted 'specific' noise level produced by the new source (usually measured using the $L_{Aeq,T}$ index) against the existing A-weighted 'background' noise level measured using the $L_{A90,T}$ index, as this is the typical level of noise that can be reasonably expected to be present the majority of the time to potentially 'mask' the new 'specific' noise. The assessment is therefore undertaken within the context of the existing noise environment. In some circumstances, it may prove equally instructive to compare the absolute level of a new specific noise against accepted absolute levels defined in standards or other relevant documents. The assessment is therefore undertaken against benchmark values, rather than against the context of the existing noise environment. Whatever approach is actually adopted for final assessment purposes, and often a combination of the two approaches is appropriate, it is important that the relevance of both contextual and benchmark assessments is at least considered in all cases.

A.44 Table 4.1 of the WHO Guidelines presents guideline benchmark values for environmental noise levels in specific environments. The noise levels relevant to residential dwellings are listed here in Table A1.

Table A1 Relevant Extracts from Table 4.1 'Guideline Values for Community Noise in Specific Environments'

Specific Environment	Critical Health Effects	$L_{Aeq,T}$	Time base (hrs)	L_{Amax} (dB)
Outdoor living area	Serious annoyance, day time and evening	55	16	-
	Moderate annoyance, day time and evening	50	16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, day time and evening	35	16	-
	Sleep disturbance, night time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoors)	45	8	60
School class rooms (included for potential effects on concentration)	Speech intelligibility, disturbance of information extraction, message communication	35	-	-